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STUDENTS' AND STUDENT TEACHERS' SENSE OF BELONGING TO SCIENCE: WHAT DO WE KNOW SO FAR?

Markus Sebastian Feser
University of Hamburg, Germany

Forming a sense of belonging to others is a fundamental need of humans as social beings (Baumeister & Leary, 1995). Meeting this fundamental need crucially influences individuals' intrinsic motivation (Ryan & Deci, 2000) and identity development (Wenger, 1999). Given this, a growing number of studies have investigated the extent to which university students' success and wellbeing in science education is related to their sense of belonging to science. This research has brought greater clarity to university students' development in science education; however, numerous aspects of university students' sense of belonging to science remain understudied. In particular, there has been insufficient research on how sense of belonging to science might moderate or influence initial science teacher education. Therefore, this editorial aims to provide an overview of the major research findings that address students' and student teachers' sense of belonging to science and to inspire future research in science (teacher) education.

What Do We Know about University Students' Sense of Belonging to Science?

To date, higher education research has mostly focused on students' sense of belonging to their university. Among other findings, this research has revealed that students' university belonging positively influences their academic satisfaction (Fischer, 2007), academic engagement (Gillen-O'Neel, 2021), and level of academic achievement (Strayhorn, 2006). However, this global perspective on sense of belonging in higher education leaves unexplored the challenges of science education (e.g., the high dropout rates in academic science programs and the under-representation of minority students; Good et al., 2012; Lewis & Hodges, 2015). Moreover, prior research has shown that the challenges associated with science education relate more to the characteristics of the culture of science (Lemke, 2001) – for example, the image of science as a "tough discipline" – than to those of a particular university. Consequently, since 2010, a growing number of studies have examined students' sense of belonging to science, instead of their university belonging.

An individual's sense of belonging to science relates to their social affiliation with and within the natural sciences. It is a complex multidimensional construct that manifests through the following five feelings and needs (Feser, 2020; Good et al., 2012; Kuchynka et al., 2019):

1. Feeling connected to people who are involved and engaged in the natural sciences.
2. Feeling acknowledged by people who are involved and engaged in the natural sciences.
3. Strong emotional wellbeing around people who are involved and engaged in the natural sciences.
4. The desire to be noticed by people who are involved and engaged in the natural sciences.
5. Feeling a special interpersonal trust towards people who are involved and engaged in the natural sciences.

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Recent studies suggest that university students' sense of belonging to science substantially correlates with their science-related mindset beliefs, their interest in sciences and their experience of achievement in the natural sciences (e.g., Lytle & Shin, 2020; Muenks et al., 2020; Rattan et al., 2018). Sense of belonging to science results from socialization through and within the natural sciences and is biographically shaped (Shin et al., 2016, p. 411). For students that belong to an underrepresented or marginalized group (e.g., women, LGBTQ students, students of color), such socialization may include experiences of discrimination or exclusion (Bilimoria & Stewart, 2009; Johnson, 2012). This may explain why these students tend to have a lower sense of belonging to science than non-marginalized groups (Cech & Rothwell, 2018; Rainey et al., 2019).

For university students, socialization through and within the natural sciences is often interlinked with academic learning experiences. However, this socialization also occurs in non-academic contexts, such as experiences within secondary science education or leisure activities related to science. Therefore, although sense of belonging to science and university belonging are associated and show close interdependencies, it is possible to differentiate between these constructs both theoretically and empirically (Feser, 2020; Findley-Van Nostrand & Pollenz, 2017).

What Do We Know about Student Teachers' Sense of Belonging to Science?

Very recently, sense of belonging to science has emerged as a topic within research on science teacher education. For example, based on earlier research, Chung-Parsons and Bailey (2019) argued that science teachers should possess a distinct sense of belonging to science, "if they are to model and foster ... [their] students' own science identity development" (p. 40). Unfortunately, student science teachers often feel labeled as second-class science students, especially within science faculties that award social status based predominantly on science-related competencies rather than teaching-related competencies (Oevermann, 2010, p. 378). This, in turn, negatively influences student teachers' sense of belonging to science.

Nevertheless, so far, only a handful of empirical studies have examined the role of sense of belonging to science in science teacher education. A qualitative study conducted by Danielsson et al. (2016) found that a lack of a sense of belonging to science is associated with a stronger sense of distance and alienation toward the natural sciences among student science teachers. Similarly, Fejes and Köpsén (2014) reported that in-service science teachers with a limited sense of belonging to science struggle to identify themselves as academic representatives of the natural sciences. Finally, a quantitative study conducted by Feser (2020) revealed that student teachers who undertake more extensive studies in science have a significantly greater sense of belonging to science than those who undertake less extensive studies, and that student teachers' sense of belonging to science moderately correlates with their academic satisfaction, their interest in science, and the extent to which they attach personal value to the natural sciences.

Implications for Future Science (Teacher) Education Research

As shown by the above overview, university students' sense of belonging to science is critical in shaping their development in science education. However, only in the last decade has research begun noticeably examining students' sense of belonging to science. Therefore, a variety of research gaps remain in this area, especially in relation to student teachers' sense of belonging to science. Among these, the following research gaps appear to be both the most pressing and potentially fruitful for further investigation:

First, most existing studies on students' sense of belonging to science are quantitative and rely on Likert-scaled questionnaires. While this approach is well suited for surveying a large number of students across universities to obtain a broad understanding of the bigger picture, more qualitative and case-based studies are needed, especially considering the biographically shaped nature of students' sense of belonging to science. Such qualitative studies would supply more profound insights into the individual development of university students.

Second, existing studies on students' sense of belonging to science have holistically considered all natural sciences, rather than comparing students by scientific discipline. Therefore, whether and to what extent students' sense of belonging to science differs depending on the scientific discipline they are studying remains unknown. A detailed analysis that accounts for students' scientific disciplines (e.g., biology, chemistry, physics, or earth sciences) is desirable.

Third, the extent to which existing findings on students' sense of belonging to science can be generalized across geographic regions is unclear. Most of the studies on students' sense of belonging to science have origi-

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nated in North America, while the few studies that address (pre-service) science teachers' sense of belonging to science were conducted in Western Europe. Further research on students' sense of belonging to science needs to be conducted in a range of geographical regions to provide evidence on possible regional or national differences.

Fourth, even though the research on student teachers' sense of belonging to science is sparse, it is reasonable to assume that the findings on students' sense of belonging to science in general are transferrable to student teachers. However, this supposition requires empirical verification. Indeed, considering that student science teachers are socialized not only in the natural sciences but also in the educational sciences, there may be some distinctions in their sense of belonging to science compared to non-teaching bound science students. Future research that compares student teachers and students not studying to become teachers in terms of their sense of belonging to science could offer insight into this supposition.

Finally, there is a lack of research examining the extent to which (student) teachers' sense of belonging to science might moderate or influence the quality of their science teaching. The few empirical studies on student teachers' sense of belonging to science suggest that such connections may be possible. Therefore, investigating the possible connection between (student) teachers' sense of belonging to science and their teaching practice may be a promising area for future research.

References

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, *117*(3), 497–529. https://doi.org/10.1037/0033-2909.117.3.497

Bilimoria, D., & Stewart, A. J. (2009). "Don't ask, don't tell": The academic climate for lesbian, gay, bisexual, and transgender faculty in science and engineering. *NWSA Journal 21*(2), 85–103. https://www.muse.jhu.edu/article/316151.

Cech, E. A., & Rothwell, W. R. (2018). LGBTQ inequality in engineering education. *Journal of Engineering Education*, *107*(4), 583–610. https://doi.org/10.1002/jee.20239

Chung-Parsons, R., & Bailey, J. M. (2019). The hierarchical (not fluid) nature of preservice secondary science teachers' perceptions of their science teacher identity. *Teaching and Teacher Education*, *78*, 39–48. https://doi.org/10.1016/j.tate.2018.11.007

Danielsson, A. T., Andersson, K., Gullberg, A., Hussénius, A., & Scantlebury, K. (2016). "In biology class we would just sit indoors…": Experiences of insideness and outsideness in the places student teachers associate with science. *Cultural Studies of Science Education*, *11*(4), 1115–1134. https://doi.org/10.1007/s11422-015-9702-8

Fejes, A., & Köpsén, S. (2014). Vocational teachers' identity formation through boundary crossing. *Journal of Education and Work*, *27*(3), 265–283. https://doi.org/10.1080/13639080.2012.742181

Feser, M. S. (2020). Sense of belonging to science—Entwicklung eines Erhebungsinstruments für Lehramtsstudierende [Development of an instrument measuring student teachers' sense of belonging to science]. *Progress in Science Education (PriSE)*, *3*(2), 10–21. https://doi.org/10.25321/prise.2020.968

Findley-Van Nostrand, D., & Pollenz, R. S. (2017). Evaluating psychosocial mechanisms underlying STEM persistence in undergraduates: Evidence of impact from a six-day pre–college engagement STEM academy program. *CBE—Life Sciences Education*, *16*(2), article 36. https://doi.org/10.1187/cbe.16-10-0294

Fischer, M. J. (2007). Settling into campus life: Differences by race/ethnicity in college involvement and outcomes. *The Journal of Higher Education*, *78*(2), 125–156. https://doi.org/10.1353/jhe.2007.0009

Gillen-O'Neel, C. (2021). Sense of belonging and student engagement: A daily study of first- and continuing-generation college students. *Research in Higher Education, 62*, 45–71. https://doi.org/10.1007/s11162-019-09570-y

Good, C., Rattan, A., & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology*, *102*(4), 700–717. https://doi.org/10.1037/a0026659

Johnson, D. R. (2012). Campus racial climate perceptions and overall sense of belonging among racially diverse women in STEM majors. *Journal of College Student Development*, *53*(2), 336–346. https://doi.org/10.1353/csd.2012.0028

Kuchynka, S., Findley-Van Nostrand, D., & Pollenz, R. S. (2019). Evaluating psychosocial mechanisms underlying STEM persistence in undergraduates: Scalability and longitudinal analysis of three cohorts from a six-day pre–college engagement STEM academy program. *CBE—Life Sciences Education*, *18*(3), Article 41. https://doi.org/10.1187/cbe.19-01-0028

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, *38*(3), 296–316. https://doi.org/10.1002/1098-2736(200103)38:3%3C296::AID-TEA1007%3E3.0.CO;2-R

Lewis, K. L., & Hodges, S. D. (2015). Expanding the concept of belonging in academic domains: Development and validation of the Ability Uncertainty Scale. *Learning and Individual Differences*, *37*, 197–202. https://doi.org/10.1016/j.lindif.2014.12.002

Lytle, A., & Shin, J. E. (2020). Incremental beliefs, STEM efficacy and STEM interest among first-year undergraduate students. *Journal of Science Education and Technology, 29*, 272–281. https://doi.org/10.1007/s10956-020-09813-z

Muenks, K., Canning, E. A., LaCosse, J., Green, D. J., Zirkel, S., Garcia, J. A., & Murphy, M. C. (2020). Does my professor think my ability can change? Students' perceptions of their STEM professors' mindset beliefs predict their psychological vulnerability, engagement, and performance in class. *Journal of Experimental Psychology: General*, *149*(11), 2119–2144. https://doi.org/10.1037/xge0000763

https://doi.org/10.33225/jbse/21.20.340

Oevermann, U. (2010). Der Gegenbegriff zur Gesellschaft ist nicht Natur sondern Kultur [The counter concept to society is not nature but culture]. In F. Herrschaft & K. Lichtblau (Eds.), *Soziologie in Frankfurt. Eine Zwischenbilanz* [Sociology in Frankfurt. An interim report] (pp. 369–406). VS Verlag für Sozialwissenschaften.
Rainey, K., Dancy, M., Mickelson, R., Stearns, E., & Moller, S. (2019). A descriptive study of race and gender differences in how instructional style and perceived professor care influence decisions to major in STEM. *International Journal of STEM Education*, *6*(1), 6. https://doi.org/10.1186/s40594-019-0159-2
Rattan, A., Savani, K., Komarraju, M., Morrison, M. M., Boggs, C., & Ambady, N. (2018). Meta-lay theories of scientific potential drive underrepresented students' sense of belonging to science, technology, engineering, and mathematics (STEM). *Journal of Personality and Social Psychology*, *115*(1), 54–75. https://doi.org/10.1037/pspi0000130
Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68
Shin, J. E. L., Levy, S. R., & London, B. (2016). Effects of role model exposure on STEM and non-STEM student engagement: Role model. *Journal of Applied Social Psychology*, *46*(7), 410–427. https://doi.org/10.1111/jasp.12371
Strayhorn, T. L. (2006). Factors influencing the academic achievement of first-generation college students. *Journal of Student Affairs Research and Practice*, *43*(4), 82–111. https://doi.org/10.2202/1949-6605.1724
Wenger, E. (1999). *Communities of practice: Learning, meaning, and identity*. Cambridge University Press.

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MODELS AND MODELLING IN SCIENCE EDUCATION IN TURKEY: A LITERATURE REVIEW

Ali Ihsan Benzer,
Suat Ünal

Abstract. *This research examined articles about models and modelling in the context of science education in Turkey by using content analysis method. Two specific academic databases; one of which was Dergipark, a platform including the academic journals published in Turkey, and Scholar Google were examined in detail so that totally 71 articles on models and modelling in science education were identified. The "article analysis form" developed by the researchers considering into the relevant literature was used to examine these articles. The findings were presented in tables and charts to show the frequency and percentile values regarding the articles examined. As a result, it was found that the purpose of most of the articles is to examine the effect of model / modelling-based teaching method. Concerning the discipline related in the articles, physics was seen to be on the top of the list, more specifically astronomy subject. As another result, qualitative research method appeared to be the most commonly used research method in the articles at hand. Lastly, it was found out that the most frequently examined variable was the mental model of the participants, and the most preferred data collection instrument was conceptual understanding test.*
Keywords: *content analysis, literature review, modelling in science, models in science, science education*

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Introduction

One of the main aims of the science education is to enable students to learn the basic concepts related to natural phenomena around them. Students are not only expected to make simple definitions of science concepts, but also to be able to make correct associations between them and to use them when explaining daily life events and situations in the world. Students can directly encounter some examples of science concepts or processes in their daily lives. For example, the student can directly experience evaporation and condensation while drinking tea at breakfast. However, it is not possible to directly observe or experience some science concepts. During the teaching of these concepts, which are called abstract concepts, the educational tools such as models and modelling (e.g., simulations, analogies, maps, diagrams, graphs) are needed. The models and modelling will help students visualize these concepts in their minds and embody abstract concepts, phenomena, or processes for them. In this context, models and modelling are of great importance, especially in the process of learning or teaching science in which there are many abstract concepts or processes. Therefore, they are at the centre of science education. In the context of science education, model and modelling are considered both as a tool and a method. In addition, they are included in contemporary teaching-learning approaches such as problem-based learning, project-based learning, design-based learning, and STEM based teaching.

Models are actually much more than concrete teaching materials used in lessons to help students understand a concept or process more easily. A model is the representation of a real object, phenomenon or process called "target" (Gilbert, 2011). Similarly, Ingham and Gilbert (1991) defined the model as the simplified representation that highlights the typical features of a system. According to Hestenes (2006), a model is a simple representation of interrelated real or imaginary structures. Models are scientific and mental activities used to make it easier to understand phenomena that look complicated (Paton, 1996). They play a major role in developing, testing, and sharing of scientific knowledge. They are also considered to be both an important element necessary for doing science and one of the consequential outcomes of scientific research (Gilbert et al., 2000). As a related concept, modelling refers to a process of building semantic relations between a specific theory and phenomena/objects (Greca & Moreira, 2000). Models and modelling are accepted as an essential part of both science and science education (Devi et al., 1996; Güneş et al., 2004; Treagust et al., 2002).

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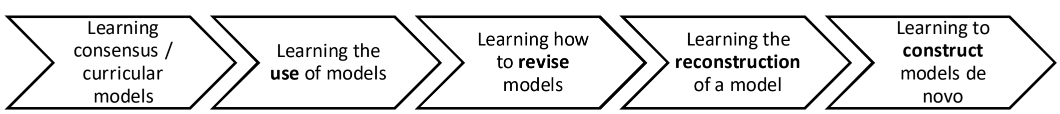
The literature seems to particularly focus on characteristics of a model rather than its definition. Van Driel and Verloop (1999) have listed the characteristics of scientific models as follows:

- A model is always associated with the target(s) it represents. The target can be a specific system, an object, a phenomenon, or a process.
- A model is a research tool used to obtain information about a target that cannot be observed or measured directly.
- A model is not in a direct interaction with the target it represents. Therefore, a photograph or a spectrum is not regarded to be a model.
- A model always differs from the target based on some distinctive details. In general, a model is simplified at the highest extent possible, excluding intentionally certain details of the target depending on the specific objectives of the research to be carried out.
- During creation of a model, the similarities and differences between the target and the model must be so clear that researchers can make predictions about what that model represents. This feature of the model is shaped by research questions in each research.
- A model comes to existence as a result of mutually influential processes, so it can be readjusted as more recent research studies are done about the target.

The review of the relevant literature shows that models are classified differently by different researchers. One of the most widely accepted classifications belongs to Harrison and Treagust (2000). Harrison and Treagust (2000) classified the models as analogical (scientific) models and personal (mental) models. Analogical models are further classified as scale models, pedagogical analogical models, symbolic (iconic) models, mathematical models, theoretical models, maps, diagrams and tables, concept process models, and simulations. On the other hand, mental models have personal and incomplete structure. A similar classification is also made by Ünal and Ergin (2006) and Ornek (2008).

Modelling can be described as the process of creating a model. It is the essence of scientific thought. Modelling is a central part of science literacy (Schwarz et al., 2009) and an essential tool for production, evaluation, and dissemination of scientific knowledge (Gilbert et al., 2000). It is a scientific process which may involve the processes of depicting the reality in detail, creating a model based on them, testing this model, and revising the model accordingly. Also, it is of great importance to bring modelling skills to students for science education. Justi and Gilbert (2002) in their research have described a procedure for teaching of modelling skills to students in science education. The phases of bringing students in modelling skill are shown in Figure 1.

Figure 1
The Phases for Acquiring Modelling Skill (Justi & Gilbert, 2002)



Using modelling process and models in teaching science is very crucial because they help students in understanding science. Modelling-based teaching is a teaching approach in which learning and teaching process is realised through modelling activities. This method also enables students to create and develop their own models so they can better understand the nature of science and related concepts by managing their own learning processes (Harrison & Treagust, 1998; Schwarz, 2009; Sins et al., 2009; Windschitl et al., 2008).

According to the Ministry of National Education of Turkey (MoNE, 2018), the goal of science education is to help students discover principles, concepts, and processes in the field of science, understand how scientific information evolves by directly participating in the scientific process, and lastly to improve their skills related to life, engineering, and design. Thus, the goal of science education can be summarised under two headings: to enable students understand basic science concepts and to enable them to acquire basic scientific behaviours or skills.

The ability of students to make sense of the events around them depends on their ability to understand basic science concepts and relate them to daily life. However, a considerable challenge faced in science teaching is students' failure to comprehend basic science concepts sufficiently. More often than not, previous research studies on science education have shown that students' levels of conceptual understanding of basic science topics (or concepts) are very low (Alkan et al., 2016; Coştu et al., 2007; Çalış, 2010; Frede, 2006; Kurnaz & Değermenci, 2012; Mann & Treagust, 2010). One notable reason for this could be the existence of abstract concepts and processes covered in science (Aksakal et al., 2015). In

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order to overcome this difficulty, model/modelling-based education, among others, can be used in teaching science. Model/modelling-based teaching of science helps students understand abstract concepts, allowing them to manage their learning processes by themselves (Chittleborough et al., 2005). Students have the opportunity to develop scientifically correct mental models thanks to the models and modelling activities used in science education (Chittleborough & Treagust, 2007). Model/modelling-based teaching increases students' conceptual understanding and success levels (Ergün & Sarıkaya, 2019; Schwarz & White, 2005), helps to eliminate their existing misconceptions (Ergün & Sarıkaya, 2014; Okumuş & Doymuş, 2018), and builds a positive attitude towards the course and learning (Türk & Kalkan, 2017).

Science courses also aim to provide students with some scientific behaviours and skills. Skill is defined as "the ability to apply knowledge, solve problems, and complete tasks" (Council of Higher Education of Turkey [CoHE], 2011). Possession of certain skills is inevitable for success in science. Modelling is one of those skills that has become quite popular in recent years. Modelling skill (ability) is a long-lasting and complex process that requires acquisition of a variety of other skills, takes fairly long and is a competence acquired gradually (Justi & Gilbert, 2002). Modelling skill is intertwined with many skills such as scientific literacy skill, scientific process skill, spatial skill, problem solving skill, and logical reasoning skill. Modelling skill both makes these skills mandatory but also contribute to development of them.

The importance of modelling skill has been noticed especially with the spread of innovative STEM/STEAM-based science teaching. Thus, many countries have modified their science curricula in order to provide students with the skill to do modelling in science. It is obvious that the countries doing well in science fields at international examinations such as PISA (Program for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study) (Singapore, South Korea, Canada and Finland) have already appreciated this and placed the deserved weight on modelling skill as a part of their curricula (Ayvacı & Bebek, 2017). Likewise, the Ministry of National Education (MoNE) of Turkey has implemented innovation on science education curriculum acknowledging modelling skill to be one of the scientific process skills to be acquired by students and underlined its importance for science education (MoNE, 2018). Besides, The MoNE has started to establish the design-skill workshops to provide students with 21st century skills as well as modelling skill (MoNE, 2021). These workshops include STEM / STEAM activities. The education reforms carried out in Turkey had a positive impact on the results of PISA 2018 and TIMSS 2019 (MoNE, 2019, 2020).

Research Aim and Research Questions

When the literature on models and modelling in science education was examined, there was no research that examines the articles about models and modelling in science and aims to reveal tendencies in these research studies. The aim of the present research was to review articles on models and modelling in the context of science education in Turkey by using content analysis so as to elicit specific tendencies or trends followed by those articles. It is expected that the results will shed light on the overall status of research studies on models and modelling in science and thus pave the way for future researchers in this area. The research question of this research can be stated as following "What trends do articles on models and modelling in science education seem to follow?". In the context of the research question, the articles published on models and modelling in science education in Turkey were examined in terms of "year", "research aim", "topic or concept", "duration of implementation", "research method", "sample group", "sample size", "research variable" and "data collection instrument(s)".

Research Methodology

General Background

In this research, the document analysis method which is one of the qualitative research methods was used to review scientific articles on models and modelling in the field of science education. Document analysis can be used both as a research method and as a data collection method (Özkan, 2019). According to Yıldırım and Şimşek (2011), document analysis means analysis of materials containing information about phenomena and happenings under scrutiny. The summative content analysis method, which is a qualitative data analysis method, was used for the analysis of the data. The main purpose of content analysis is to gather similar data within the framework of certain concepts and themes and to interpret them in a way that the reader can understand (Yıldırım & Şimşek, 2011). The themes to be examined in the summative content analysis can be determined before or during the data analysis (Hsieh & Shannon, 2005). This research was conducted between May and July in 2020. The scope of the research was limited to empirical articles conducted from 2002-2019 on models and modelling in science education in Turkey.

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In the content analysis method, the information on the credentials of the examined research studies, their results or suggestions are presented to the audience in a more systematic manner by reviewing the literature on the subject under consideration, so that this type of research sheds light on new research studies to be conducted in the relevant field.

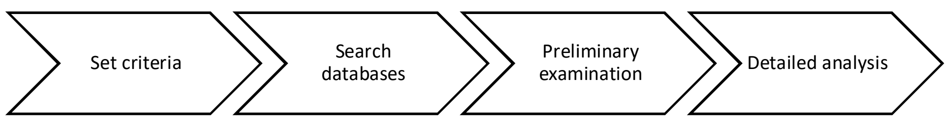
Sample

It was determined that 71 articles were conducted on models and modelling in science education in Turkey between the years of 2002 and 2019. All of these articles related to the purpose of the research have been included in the research. Therefore, the sample of the research consisted of 71 articles on models and modelling in science education from 2002 to 2019 in Turkey.

Instrument and Procedures

As seen in Figure 2, data collection and analysis of this research was completed in four stages. To start with, inclusion criteria were determined to select articles for review. Secondly, a search was done in the academic databases for access to articles that fell under the scope of this research. In the third step, articles complying with the criteria were picked up, downloaded, and subjected to preliminary review. Finally, those articles were analysed in detail by using summative content analysis.

Figure 2
The Steps for Data Collection and Analysis



As mentioned above, decision of inclusion or exclusion was made according to the inclusion criteria, which are given below:

- Articles must be published in a Turkish journal,
- Articles must be about science education,
- Articles must deal with models or modelling,
- Articles must be published in or prior to the year 2019,
- Articles must be available online.

On the other hand, articles were excluded if they were;

- Review research studies,
- Purely theoretical research studies,
- Scale development research studies,
- Document analysis research studies.

After deciding on suitable articles, a search was performed in online databases of Dergipark and Scholar Google and only those containing the term "Model" in the title were put on the list. Dergipark is a platform that offers electronic media and editorial process management service for academic journals published in Turkey (Dergipark, 2020). A preliminary review was conducted on the articles selected at this stage considering the main aim and inclusion criteria of this research. A total of 71 articles were determined and saved for detailed analysis. For analysing and coding the articles, a form called "Article Analysis Form (AAF)" was employed. During the preparation of the form, similar review articles (e.g., Albayrak & Çiltaş, 2017; Aztekin & Taşpınar-Şener, 2015; Küçüközer, 2016; O'Toole et al., 2018) performed in different fields by using descriptive analysis or content analysis were utilized and taken into consideration. The AAF was finalised in view of the aim of the current research. The final version of the AAF is attached as Appendix 1 to this article.

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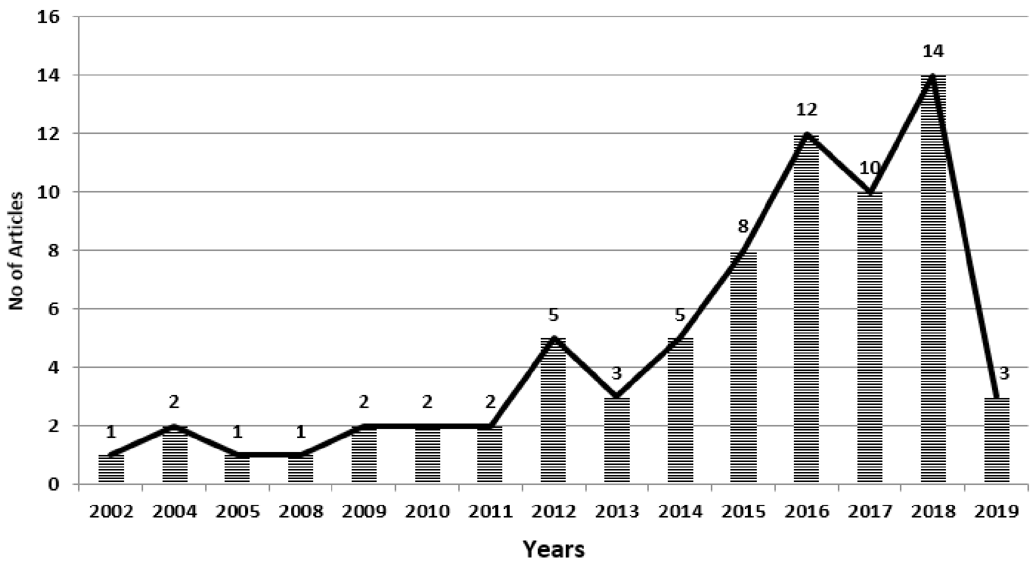
Data Analysis

The articles were coded by two independent coders using the AAF. For the reliability of the research, Cohen Kappa statistics between the coders were calculated. The resulting Cohen Kappa coefficient (>0.80) indicated an excellent level of compatibility between coders (Landis & Koch, 1977). The AAF was used to code the selected articles by the year of publication, research aim, selected focused science topic or concept, research method, sample group, sample size, research variable examined, data collection instrument, and duration of the implementation. The data obtained from the AAF were tabulated and displayed in charts along with figures of percentile and frequency.

Research Results

The results from the AAF were exhibited incorporating the percentile and frequencies in graphics and tables by using descriptive statistical methods. The distribution of the articles by year is shown in Figure 3.

Figure 3
Distribution of Articles by Year



As seen in Figure 3, there was an increase in the number of articles falling in the scope of this research, except during year 2019. It was found that the most articles on the topic of concern were published in 2018 (14 articles, 19.7%). Table 1 displays the distribution of the articles by research aim.

Table 1
Distribution of Articles by Research Aim

Aim	*f*	%
To determine the effects of model or modelling-based teaching	34	45.9
To examine mental models	24	32.4
To examine the views on the nature of models and modelling	10	13.5
To examine the views on model or modelling-based teaching	3	4.1
To examine the process of modelling	2	2.7
Other	1	1.4
Total	**74**	**100**

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It is understood from Table 1 that the majority of the articles reviewed here share the same research aim: to determine the effects of model or modelling-based teaching method (45.9%). The same articles were seen to determine the effectiveness of model/modelling-based teaching mostly by using experimental and control groups. Most of them were directed to increase the participants' understanding levels on selected concepts or their achievement level on the selected topic. The second most popular research aim was noted to be examining the participants' mental models regarding the selected science topic often by using open-ended questions and drawings as data collection instruments in a case/or descriptive research. The category "Other" covered one different research aim, which is comparison of scientific models in the science coursebooks with the mental models drawn by the students. The number of research aims was calculated bigger than the sum of the research studies reviewed since some of the articles had two or even three separate research aims. Table 2 shows the distribution of the articles in connection with the science topic or concept dealt.

Table 2
Distribution of Articles by Topic or Concept Dealt

Field	Topic	*f*	%	*f*	%
Biology				14	21.9
	Cell and Its Structure	4	6.3		
	Environment	2	3.1		
	Respiratory System	2	3.1		
	Plants	1	1.6		
	Urinary System	1	1.6		
	Circulatory System	1	1.6		
	Genetics	1	1.6		
	Microorganisms	1	1.6		
	Digestive System	1	1.6		
Physics				26	40.6
	Astronomy	14	21.9		
	Electricity	4	6.3		
	Work, Power, Energy	2	3.1		
	Sound	2	3.1		
	Light	1	1.6		
	Photoelectricity	1	1.6		
	Radioactivity	1	1.6		
	Optics	1	1.6		
Chemistry				24	37.5
	Matter and Heat	12	18.8		
	Atom and Its Structure	8	12.5		
	Chemical Reactions	3	4.7		
	Acid and Base	1	1.6		
Total				**64**	**100**

As Table 2 shows, physics was the most heavily examined field (40.6%). As for the subject of physics, astronomy, which encompasses the study of the Earth, the Sun, the Moon and space, was found to be the most frequently dealt topic (21.9%). On the contrary, the least research studies were carried out in the discipline of biology (21.9%). In some research studies covered here, more than one topic or concept was examined, while in some research studies, no topic was examined.

When the analysis of aims of the articles was further detailed (see Table 1), it was noticed that 34 of the 71 articles included some type of intervention (teaching practice). In those research studies, it was aimed at exploring the effectiveness of the teaching practices applied from various angles. The distribution of the teaching activities by duration is given in Table 3. However, some of them (*n*=6) did not report the duration of the teaching intervention.

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Table 3
Distribution of Articles by Duration of Implementation

Duration	*f*	%
1-3 weeks	10	29.4
4-6 weeks	15	44.1
7-9 weeks	1	2.9
10 weeks and above	2	5.9
Non-specified	6	17.7
Total	**34**	**100**

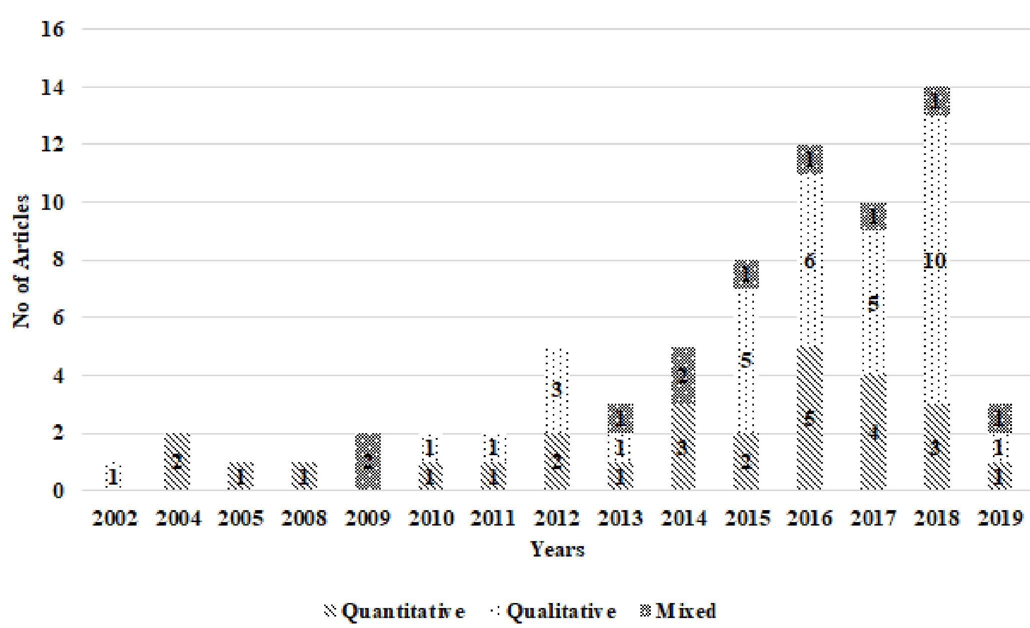
As can be seen in Table 3, the research studies with the practical period of 4 to 6 weeks had the biggest portion (44.1%) in the articles examined.

Apart from the foregoing, the distribution of the articles by used research method and distribution of the research method preference across years are displayed in Table 4 and Figure 4, respectively.

Table 4
Distribution of Articles by Research Method

Research Method	*f*	%
Qualitative	34	47.9
Quantitative	27	38.0
Mixed	10	14.1
Total	**71**	**100**

Figure 4
Distribution of research methods by year



As seen in Table 4 and Figure 4, the research methods of the articles were collected under three headings as quantitative method, qualitative method, and mixed method. During the analysis of the research methods, atten-

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tion was paid to the type of data collected and data analysis methods as well as research methods reported in the article. In this respect, the examples with qualitative data (e.g., interview, citation) and qualitative data analysis methods only (e.g., content analysis, descriptive analysis) were named as qualitative; whereas they were coded as quantitative if quantitative data (e.g., data obtained from Likert scale or multiple-choice tests) and quantitative data analysis methods (e.g., t-test, ANOVA) were used only, and a blend of both of the abovementioned types of data led to the labelling as mixed type research method (Teo et al., 2014). It is understood from Table 4 that qualitative method was dominantly used in the articles (47.9%). In addition, Figure 4 shows that the number of qualitative research studies formed an incremental curve towards the end of the bar of years. The same is true for the number of quantitative research studies. However, the proportion of qualitative research studies tended to increase besides their number in the whole. As another sub-problem, the distribution of the articles here by their sample group is given in Table 5.

Table 5
Distribution of Articles by Sample Group

Sample	Sample Group	*f*	%	*f*	%
Postgraduate		1	0.8	1	0.8
Undergraduate				29	24.2
	Pre-service Biology Teachers	2	1.7		
	Pre-service Science Teachers	15	12.5		
	Pre-service Physics Teachers	3	2.5		
	Pre-service Chemistry Teachers	5	4.2		
	Pre-service Mathematics Teachers	3	2.5		
	Pre-service Pre-school Teachers	1	0.8		
High school (9-12)				6	5.0
	11th grade	1	0.8		
	10th grade	3	2.5		
	9th grade	1	0.8		
	Not specified	1	0.8		
Secondary school (5-8)				47	39.2
	8th grade	8	6.7		
	7th grade	20	16.7		
	6th grade	13	10.8		
	5th grade	6	5.0		
Primary school (1-4)				8	6.7
	4th grade	6	5.0		
	3rd grade	1	0.8		
	2nd grade	1	0.8		
Pre-school		4	3.3	4	3.3
Teacher/Lecturer				25	20.8
	Biology Teacher	4	3.3		
	Science Teacher	6	5.0		
	Physics Teacher	5	4.2		
	Chemistry Teacher	4	3.3		
	Mathematics Teacher	4	3.3		
	Lecturer	1	0.8		
	Primary School Teacher	1	0.8		
Total			100	120	100

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Table 5 demonstrates that the research studies reviewed here were chiefly carried out with secondary school students (39.2%), particularly 7th graders (16.7%). Of the samples at undergraduate level (24.2%), the most commonly examined sample group was found to be pre-service science teachers (12.5%). Some of the research studies consisted of heterogeneous sample groups, such as picking up of learners from various grade levels or both teachers and students at one time (Aydın et al., 2018; Görecek-Baybars & Çil, 2019; Şeren & Doğru, 2018). As for two-year associate programs or vocational high schools, none of the articles were found to target students attending those kinds of schools. Lastly, it was determined that the number of research studies implemented with learners from pre-school, primary and high school was quite low. The distribution of the articles by sample size is given in Table 6.

Table 6
Distribution of Articles by Sample Size

Sample Size	*f*	%
1-30 persons	13	18.3
31-60 persons	20	28.2
61-90 persons	12	16.9
91-120 persons	11	15.5
121 and above	15	21.1
Total	**71**	**100**

It can be seen in Table 6 that 28.2% of the articles reported results obtained from 31 to 60 participants. As another consideration in this research, the distribution of the articles by examined variables is shown in Table 7.

Table 7
Distribution of Articles by Variable Examined

Variable	*f*	%
Mental Model	26	27.7
Participants' Views	22	23.4
Level of Conceptual Understanding	19	20.2
Achievement Level	9	9.6
Misconceptions	5	5.3
Permanence of Learning	3	3.2
Attitude	3	3.2
Modelling Competence	2	2.1
Other	5	5.3
Total	**94**	**100**

Table 7 reveals that mental model (27.7%) and participants' views (23.4%) were the most commonly examined variables in all of the articles considered here. The articles in the category "Other" were seen to examine variables such as metacognitive awareness, creativity, spatial ability, conceptual change, and anxiety. Most of the research studies were conducted to examine more than one variable. Among categorical variables, it was seen that class level and gender were the most widespread factors, respectively. For instance, Bakaç and Kartal-Taşoğlu (2016) compared the effectiveness of the traditional teaching method and modelling-based teaching method in eliminating misconceptions of pre-service physics teachers about radioactivity subject according to gender. No significant difference was found between the participants' pre- and post-test results or scores obtained by the males and females. As another finding worth noting, it was seen that the selected variables did not include the 21st century's essential skills such as problem solving, critical thinking and reflective thinking. The distribution of the articles by data collection instruments is demonstrated in Table 8.

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Table 8
Distribution of Articles by Data Collection Instruments Employed

Data Collection Instrument	*f*	%
Conceptual Understanding Test	40	41.2
Questionnaire/Scale	22	22.7
Interview	20	20.6
Achievement Test	9	9.3
Document analysis rubric (Coursebook, students' activity documents, etc.)	3	3.1
Skill Test	2	2.1
Observation	1	1.0
Total	97	100.0

Table 8 points out that conceptual understanding tests became the most frequently used data collection instrument in all of the research studies (41.2%). Still, many research studies were realised with more than one single data collection instrument. The majority of the conceptual understanding tests comprised of open-ended items that require drawings. When it comes to those employing questionnaires/scales, it was seen that almost half of them used the questionnaire on the participants' views of models and modelling developed by Güneş et al. (2004), while the rest of them used their questionnaires/scales developed by themselves. As for the achievement tests, they were mostly in the form of multiple-choice tests. The skill tests included tests on creativity and spatial skills.

Discussion

In this research, an examination was carried out on Turkish articles discussing models and modelling in science education in order to expose the patterns of trends they follow. This section is dedicated to give an account of the findings and compare them with similar research studies.

First of all, it was seen that the first article about models and modelling in science education in Turkey was published in 2002, there was an increase in the number of such publications on an annual basis since then, the year 2019 being an exception, and the peak level was reached in 2018, the last of the years covered here. The reason for the tendency of rise could be the fact that the Ministry of National Education of Turkey adopted a revision on the science curriculum in 2013 and announced modelling to be a skill necessary for the field of science, which brought the topic to the attention of researchers. Albayrak and Çiltaş (2017), in his research, examined the obvious tendencies exhibited by research papers published in Turkey between 2004 and 2015 on mathematical modelling in the scope of mathematics education, and found out that the number of research studies on that topic was on the rise as years passed, not steadily though. It seems that the findings from Albayrak and Çiltaş (2017) lend support to the findings in the current research.

The analysis of the articles by aim of research demonstrated that the first place was occupied by the examination of the effectiveness of model/modelling-based teaching. In those research studies, the effect of that teaching style was often checked by using experimental and control groups. In the articles with this purpose, it is aimed to increase the levels of conceptual understanding or achievements of the participants by means of model or modelling based education. Albayrak and Çiltaş (2017) stated that the existing research studies on mathematical modelling generally aimed at teaching the participants mathematics by means of model/modelling-based teaching activities. It can thus be said that the results of this research are in congruence with those of Albayrak and Çiltaş (2017). Another prominent research aim adopted here was to bring out the participants' mental models in terms of various science topics or concepts by using data collection instruments such as open-ended questions that require drawings in the case or descriptive research studies examined.

Moreover, it was found out that the discipline which was examined most of all in the articles here was physics, astronomy standing out as the most frequently covered subject, which covers "the earth", "the sun", "the moon", and "the universe" concepts. In this regard, biology proved to be the least examined discipline/field, and "the cell and its structure" is most research study subject in the discipline of biology. The popularity of astronomy among the research studies in the scope could be due to the fact that astronomy subjects include macro phenomena or happenings and that most students have difficulty in understanding these events or concepts. Küçüközer (2016), in her far-reaching review of doctoral dissertations in science education, noted that physics was dealt with most respect to topics of force and movement, biology with

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respect to humans and the environment, and chemistry was examined in relation with the structure of matter. Doğru et al. (2012), in their analysis of postgraduate dissertations in science education, noted that the trendiest topics were "eco-system and ecology", "electricity", and "the structure of atom" in biology, physics, and chemistry education, respectively. The results of current research seem to be at variance with the findings obtained by Küçüközer (2016) and Doğru et al. (2012). It could be accounted for by the inclination towards topics posing specific difficulty of conceptual understanding when models and modelling come to attention. Besides this, it was observed in the research studies examined that the emphasis was placed on abstract topics (atom, heat, cell, etc.) and processes (the circulatory system, chemical reactions, etc.) that can be hardly visualised.

When analysed from the perspective of research method used, it was concluded that qualitative research method became the most preferential method. This finding is compatible with the previous review works on science education research (O'Toole et al., 2018) and mathematical model and modelling research studies (Albayrak & Çiltaş, 2017; Aztekin & Taşpınar-Şener, 2015). Nevertheless, it is not in compliance with the results of the review research focusing on chemistry education (Teo et al., 2014; Ulutaş et al., 2015), science education (Küçüközer, 2016) or instructional technologies (Göktaş et al., 2012; Hrastinski & Keller, 2007). As an obvious difference, the intensive preference for qualitative methods in current case can be said to be linked with the aims of the specific articles analysed here. In other words, the authors might have chosen a different research method each time considering its suitability for the specific facts of their research such as the discipline, aim, topic or year in question.

When the articles are analysed in terms of their samples, it becomes apparent that the most preferred sample group in the articles is secondary school students. More specifically, the 7th grade was noted as the most frequently preferred class level in secondary school. The second most common sample group was found to be pre-service science teachers. In a similar vein, Küçüközer (2016), in her review about doctoral dissertations in science education, indicated that the majority of the theses were conducted with secondary school students and especially with the 7th grade students. This leads to full congruence with current findings. On the other hand, there are some reports from review works on chemistry education (Teo et al., 2014; Ulutaş et al., 2015), mathematical models and modelling (Albayrak & Çiltaş, 2017; Aztekin & Taşpınar-Şener, 2015), physics education (Kaltakçı-Gürel et al., 2017; Önder et al., 2013) and biology education (Gül & Sözbilir, 2015) that the majority of those research studies were conducted on students at undergraduate level. It shows partial congruence with the current research as the latter noted that undergraduate students represented the second most common group of participants after secondary schoolers. As for sample size, the research studies examined here were prevalently implemented with 31 to 60 participants. It is in consensus with findings from other review research studies including physics education (Kaltakçı-Gürel et al., 2017; Önder et al., 2013), chemistry education (Sözbilir et al., 2013), biology education (Gül & Sözbilir, 2015) and instructional technologies (Göktaş et al., 2012). The sample group and sample size can vary depending on the aim, method, and other crucial aspects of each research, yet undergraduate students may have been preferred basically for convenience.

As another angle of current research, we found that the most widely examined variable was the mental models of the participants. In contrast, achievement was reported as the most prevalent variable in reviews of research studies in science education (Deniş-Çeliker & Uçar, 2015), physics education (Önder et al., 2013), chemistry education (Ulutaş et al., 2015) and biology education (Gül & Sözbilir, 2015). Bearing in mind that science includes abstract concepts or processes, it looks plausible to examine mental models more often than other variables in research studies on models and modelling in the field of science. Moreover, what matters most for the level of understanding and achievement of students on a particular topic is whether they possess scientifically correct mental models for the concepts or phenomena on that topic. It can thus be argued that it is a prerequisite to identify students' existing mental models for effective concept teaching. On the grounds of these two reasons, one would smoothly anticipate mental models as the most researched variable. However, it is a regrettable fact that no research studies were found to deal with the relationship between modelling skill and the vital skills for the 21st century, which had caused the curriculum to be revised and updated, such as problem solving, critical thinking, communication, information management and collaboration skills (Ananiadou & Claro, 2009; Binkley et al., 2012; Voogt & Roblin, 2012). It deserves consideration as employing modelling skill in science classes could possibly improve critical thinking, abstraction, and problem-solving skills. As another remarkable point, most of the research studies analysed here targeted cognitive domain, while there were only few examples looking over affective factors that could have a direct or indirect impact on learning such as attitude, motivation, anxiety, self-efficacy and self-confidence.

Considering the data collection instruments, it was seen that conceptual understanding tests were the most preferred tools. Most of such tests were comprised of open-ended questions which required the respondents to make drawings. Recalling that most research studies attempted to determine the mental models and the effectiveness of model or modelling-based education, it would not be surprising to come across that kind of questions as data collection instruments. The

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most widely used data collection instruments appeared to be achievement tests in research studies concerning biology education (Gül & Sözbilir, 2015), science education (Küçüközer, 2016), and physics education (Kaltakçı-Gürel et al., 2017), while it was reported to be interviews by Albayrak and Çiltaş (2017) in his review on mathematical models and modelling. It is known that the goal of research examination of the effect of model/modelling-based education is to increase levels of conceptual understanding. For this reason, conceptual understanding tests were expectedly commonplace in the current research. It should be still noted that more than one data collection instrument was employed in most of the research studies examined here.

As the final sub-question of this research, it was found that the majority of the articles feature a teaching intervention applied to the participants. All of them can be seen to have intended to explore the effect of model/modelling-based teaching on a range of variables. They were not completed in the same period of time, and they mostly lasted for 4 to 6 weeks before completion of the experimental stage. Similarly, Kozikoğlu and Senemoğlu (2015), in their review on doctoral dissertations about education curricula and instruction, reached the conclusion that a vast number of such research studies completed their practical component within 4 to 8 weeks. In this respect, there can be seen conformity between the abovementioned research and the current one at a certain extent.

Conclusions and Implications

The aim of the research was to review articles on models and modelling in the context of science education in Turkey by using content analysis so as to elicit specific tendencies or trends followed by those articles. The articles were examined in terms of "year", "research aim", "topic or concept", "duration of implementation", "research method", "sample group", "sample size", "research variable" and "data collection instrument(s)". As a result, it was found that the purpose of most of the articles is to examine the effect of model / modelling-based teaching method. Concerning the discipline related in the articles, physics was seen to be on the top of the list, more specifically astronomy subject. As another result, qualitative research method appeared to be the most commonly used research method in the articles at hand. Lastly, it was found out that the most frequently examined variable was the mental models of the participants, and the most preferred data collection instrument was conceptual understanding test.

In view of the findings and discussion above, a number of recommendations were made for future researchers that are interested in models and modelling in science education.

- Even though most of the research studies in the field of science education have been carried out by using models designed by teachers, it is suggested to design learning environments to test their effectiveness in which students are supposed to create models and develop their modelling skills in future attempts.
- The relevant research studies have predominantly been planned to explore the effect of model/modelling-based teaching on students' achievement and mental models. In the future, unlike the inclination recorded so far, bigger emphasis could be placed onto affective traits of learners such as attitude, motivation, self-efficacy, and anxiety instead of cognitive variables.
- Again, future research studies can be directed towards portrayal of the relationship between model/modelling-based education and the skills needed in the 21st century such as problem solving, critical thinking, reflective thinking, communication, and collaboration.
- It is of great importance that young learners have more accurate mental models of basic concepts for them to be able to configure upper level concepts more accurately in their minds. To this end, concentration should be shifted onto learners in earlier years of education, which are pre-school and primary school levels.
- The MoNE of Turkey has made important innovations in the field of education. The MoNE has renewed all education curricula at primary, secondary and high school levels in the context of 21st century skills in 2018. In the new science curriculum, modelling skill was emphasized as an important skill that should be acquired by students. Also, the MoNE has started to establish the STEM-based design-skill workshops. These workshops offer valuable opportunities for students to develop their modelling skills. As a result of the education reforms, Turkey's PISA and TIMSS scores started to rise. The interest of researchers in Turkey on the model and modelling is increasing because of the emphasis on the importance of modelling skill in the renewed science curriculum, and the popularization of STEM-based design-skill workshops that include modelling activities. Research studies on modelling are invaluable and offer opportunities to increase the country's science literacy. With this research, the trends of articles on models and modelling in science education in Turkey were presented and the gaps in research studies were reported. A similar research can be carried out for a different country, and the results obtained can be compared in terms of countries' PISA and TIMSS scores.

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- In recent years, especially during the Covid-19 pandemic, content analysis studies have attracted the attention of many researchers and their number has increased day by day. Researchers working on a particular subject generally spend a lot of time to reach research studies on this subject in the relevant literature. At this point, content analysis studies provide important convenience. These types of research studies are of great importance not only for researchers working on this subject, but also for researchers who are just beginning to identify a research problem or subject to be examined. These researchers not only have the opportunity to see what kind of research studies have been conducted on a particular subject through, but also have the opportunity to see more clearly what gaps are in literature and which problems have not yet been examined. In addition, once researchers become aware of current research topics and trends in the literature, they may wish to do research on these topics. Therefore, the results of content analysis studies guide research studies on future. It can be said that this research is important because the articles on models and modelling in science education in Turkey were examined and evaluated in a comprehensive and holistic manner. The researchers who realize what kind of research studies are done in different countries can carry out the similar research studies in their own countries.

References

Aksakal, M., Karataş, A., & Laçin-Şimşek, C. (2015). Mayoz bölünme konusunun öğretiminde modellerle zenginleştirilmiş laboratuvar ortamının akademik başarıya etkisi [The effect of a laboratory environment enriched with models on academic success within the scope of teaching the subject of meiosis]. *Pamukkale University Journal of Education*, *37*(1), 49-60.

Albayrak, E, & Çiltaş, A. (2017). Türkiye'de matematik eğitimi alanında yayınlanan matematiksel model ve modelleme araştırmalarının betimsel içerik analizi [Descriptive content analysis of mathematical modeling research published in the field of mathematics education in Turkey]. *International Journal of Turkish Education Sciences, 2017*(9), 258-283.

Alkan, İ., Akkaya, G., & Köksal, M. S. (2016). Fen bilgisi öğretmen adaylarının mitoz ve mayoz bölünmeye ilişkin kavram yanılgılarının model oluşturma yaklaşımıyla belirlenmesi [Determining misconceptions of prospective science teachers by using modeling approach as a data collection way]. *Ondokuz Mayis University Journal of Faculty of Education*, *35*(2), 121-135.

Ananiadou, K., & Claro, M. (2009). *21st century skills and competences for new millennium learners in OECD countries*. OECD education working paper no. 41. OECD Publishing. https://doi.org/10.1787/218525261154

Aydın, S., Ural-Keleş, P., & Hafızoğlu, H. (2018). The mental models of the secondary school students about the Sun, the Earth and the Moon system. *International Journal of Eurasia Social Sciences*, *9*(34), 2425-2437.

Ayvacı, H. Ş., & Bebek, G. (2017). 2013 yılında revize edilen fen bilimleri dersi öğretim programı'nda yer alan kazanımların incelenmesi: Model oluşturma ve kullanma konusu [Analysis of gains took place in science course teaching program revised in 2013: Subject of forming model and using model]. *HAYEF Journal of Education*, *14*(1), 89-104.

Aztekin, S., & Taşpınar-Şener, Z. (2015). The content analysis of mathematical modelling studies in Turkey: A meta-synthesis study. *Education and Science, 40*(178), 139-161. https://doi.org/10.15390/EB.2014.4125

Bakaç, M., & Taşoğlu, A. (2016). Fizik öğretmen adaylarının radyoaktivite konusundaki kavram yanılgılarının giderilmesinde modellemenin etkisi [The effect of modeling in removing the misconceptions on radioactivity of prospective physics teachers]. *Gazi Journal of Education Sciences*, *2*(3), 181-192.

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and teaching of 21st century skills* (pp. 17-66). Springer. https://doi.org/10.1007/978-94-007-2324-5_2

Çalış, S. (2010). The level of understanding of elementary education students' some chemistry subjects. *Procedia-Social and Behavioral Sciences, 2*(2), 4868-4871. https://doi.org/10.1016/j.sbspro.2010.03.786

Chittleborough, G. D., Treagust, D. F., Mamiala, T. L., & Mocerino, M. (2005). Students' perceptions of the role of models in the process of science and in the process of learning. *Research in Science & Technological Education*, *23*(2), 195-212. https://doi.org/10.1080/02635140500266484

Chittleborough, G., & Treagust, D. F. (2007). The modelling ability of non-major chemistry students and their understanding of the sub-microscopic level. *Chemistry Education Research and Practice*, *8*(3), 274-292. https://doi.org/10.1039/B6RP90035F

Coştu, B., Ayas, A., & Ünal, S. (2007). Kavram yanılgıları ve olası nedenleri: Kaynama kavramı [Misconceptions about boiling and their possible reasons]. *Kastamonu Education Journal, 15*(1), 123-136.

Council of Higher Education of Turkey (CoHE) (2011). Türkiye yükseköğretim yeterlilikler çerçevesi [National qualifications framework for higher education in Turkey]. *YÖK*. http://tyyc.yok.gov.tr/dosyalar/21122011-TYYC%20Yonetmeligi-Taslak.doc

Deniş-Çeliker, H. D., & Uçar, C. (2015). Fen eğitimi araştırmacılarına bir rehber: 2001-2013 yılları arasında yazılan lisansüstü tezlerin incelenmesi [A guide for science researchers: Examination of thesis written between 2001-2013 years]. *Electronic Journal of Social Sciences, 14*(54), 81-94.

Dergipark. (2020). About Dergipark. *Dergipark*. https://dergipark.org.tr/tr/pub/page/about

Devi, R., Tiberghien, A., Baker, M., & Brna, P. (1996). Modelling students' construction of energy models in physics. *Instructional Science, 24*(4), 259-293. https://doi.org/10.1007/BF00118052

Doğru, M., Gençosman, T., Ataalkın, A. N., & Şeker, F. (2012). Fen bilimleri eğitiminde çalışılan yüksek lisans ve doktora tezlerinin analizi [Analysis of the postgraduate and doctoral theses conducted on sciences education]. *Journal of Turkish Science Education, 9*(1), 49-64.

Ergün, A., & Sarıkaya, M. (2014). The effects of the model-based activities on overcoming the misconceptions regarding the particulate natured structure of the matter. *E-Journal of New World Sciences Academy*, *9*(3), 248-275.

Ergün, A., & Sarıkaya, M. (2019). The effect of model-based learning on the academic success and conceptual understanding of middle-school students on the subject of the particulate nature of matter. *Electronic Journal of Social Sciences*, *18*(72), 2059-2075. https://app.trdizin.gov.tr/publication/paper/detail/TXpFM05ESXlNZz09

Frede, V. (2006). Pre-service elementary teacher's conceptions about astronomy. *Advances in Space Research*, *38*(10), 2237-2246.

Gilbert, J. K., Boulter, C. J., & Elmer, R. (2000). Positioning models in science education and in design and technology education. In J. K. Gilbert & C. J. Boulter (Eds.), *Developing models in science education* (pp. 3-7). Springer. https://doi.org/10.1007/978-94-010-0876-1_1

Gilbert, S. W. (2011). *Models-based science teaching: Understanding and using mental models.* National Science Teachers Association (NSTA) Press.

Göktaş, Y., Küçük, S., Aydemir, M., Telli, E., Arpacık, Ö., Yıldırım, G., & Reisoğlu, İ. (2012). Educational technology research trends in Turkey: A content analysis of the 2000-2009 decade. *Educational Sciences: Theory & Practice*, *12*(1), 177-199.

Görecek-Baybars, M., & Çil, M. (2019). Ortaokul öğrencilerinin "Güneş Sistemi" ile ilgili zihinsel modelleri [Secondary school students' mental models about "Solar System"]. *Anemon Journal of Social Sciences of Mus Alparslan University*, *7*, 37-46. https://doi.org/10.18506/anemon.521940

Greca, M. I., & Moreira, M. A. (2000). Mental models, conceptual models, and modelling. *International Journal of Science Education, 22*(1), 1-11. https://doi.org/10.1080/095006900289976

Gul, Ş., & Sozbilir, M. (2015). Biology education research trends in Turkey. *Eurasia Journal of Mathematics, Science & Technology Education, 11*(1), 93–109. https://doi.org/10.12973/eurasia.2015.1309a

Güneş, B., Gülçiçek, Ç., & Bağcı, N. (2004). Eğitim fakültelerindeki fen ve matematik öğretim elemanlarının model ve modelleme hakkındaki görüşlerinin incelenmesi [Analysis of science educators' views about model and modelling]. *Journal of Turkish Science Education, 1*(1), 35-48.

Harrison, A. G., & Treagust, D. F. (1998). Modelling in science lessons: Are there better ways to learn with models? *School Science and Mathematics, 98*(8), 420-429. https://doi.org/10.1111/j.1949-8594.1998.tb17434.x

Harrison, A. G., & Treagust, D. F. (2000). A typology of school science models. *International Journal of Science Education, 22*(9), 1011-1026. https://doi.org/10.1080/095006900416884

Hestenes, D. (2006, August). Notes for a modelling theory of science, cognition and instruction. In E. van den Berg, T. Ellermeijer, & O. Slooten (Eds.), *Proceedings GIREP Conference 2006: Modelling in physics and physics education* (pp. 34-65). University of Amsterdam.

Hrastinski, S., & Keller, C. (2007). An examination of research approaches that underlie research on educational technology: A review from 2000 to 2004. *Journal of Educational Computing Research, 36*(2), 175-190. https://doi.org/10.2190/H16L-4662-6000-0446

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, *15*(9), 1277-1288. https://doi.org/10.1177/1049732305276687

Ingham, A. M., & Gilbert, J. K. (1991). The use of analogue models by students of chemistry at higher education level. *International Journal of Science Education, 13*(2), 193-202. https://doi.org/10.1080/0950069910130206

Justi, R. S., & Gilbert, J. K. (2002). Modelling, teachers' views on the nature of modelling, and implications for the education of modellers. *International Journal of Science Education*, *24*(4), 369-387. https://doi.org/10.1080/09500690110110142

Kaltakçı-Gürel, D., Sak, M., Ünal, Z. Ş., Özbek, V., Candaş, Z., & Şen, S. (2017). 1995-2015 yılları arasında Türkiye'de fizik eğitimine yönelik yayınlanan makalelerin içerik analizi [Content analysis of physics education articles published in Turkey between 1995 and 2015]. *Mehmet Akif Ersoy University Journal of Education Faculty, 42*, 143-167.

Kozikoğlu, İ., & Senemoğlu, N. (2015). The content analysis of dissertations completed in the field of curriculum and instruction (2009-2014). *Education and Science*, *40*(182), 29-41.

Küçüközer, A. (2016). Fen bilgisi eğitimi alanında yapılan doktora tezlerine bir bakış [An overview of the doctoral thesis in science education]. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 10*(1), 107-141.

Kurnaz, M. A., & Değermenci, A. (2012). 7. sınıf öğrencilerinin güneş, dünya ve ay ile ilgili zihinsel modelleri [Mental models of 7th grade students on sun, earth, and moon]. *Elementary Education Online, 11*(1), 137-150.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, *33*(1), 159-174. https://doi.org/10.2307/2529310

Mann, M., & Treagust, D. F. (2010). Students' conceptions about energy and the human body. *Science Education International*, *21*(3), 144-159.

Ministry of National Education of Turkey (MoNE) (2018). Fen bilimleri dersi öğretim programı (İlkokul ve ortaokul 3, 4, 5, 6, 7 ve 8. sınıflar) [Science Course Curriculum (Primary and Secondary School 3, 4, 5, 6, 7 and 8th Grades)]. *MEB*. http://mufredat.meb.gov.tr/Dosyalar/201812312311937-FEN%20B%C4%B0L%C4%B0MLER%C4%B0%20%C3%96%C4%9ERET%C4%B0M%20PROGRAMI2018.pdf

Ministry of National Education of Turkey (MoNE) (2019). PISA 2018 Türkiye ön raporu [PISA 2018 preliminary report of Turkey]. *MEB*. http://pisa.meb.gov.tr/wp-content/uploads/2020/01/PISA_2018_Turkiye_On_Raporu.pdf

Ministry of National Education of Turkey (MoNE) (2020). TIMSS 2019 Türkiye Ön Raporu [TIMSS 2019 preliminary report of Turkey]. *MEB*. http://www.meb.gov.tr/meb_iys_dosyalar/2020_12/10173505_No15_TIMSS_2019_Turkiye_On_Raporu_Guncel.pdf

Ministry of National Education of Turkey (MoNE) (2021). Tasarım beceri atölyeleriyle 1 yılda yaklaşık 6 bin okulun koridoru hayat sahnesine dönüştü [Approximately 6 thousand schools' corridor transformed into a life stage in 1 year by design skill workshops]. *MEB*. https://tba.meb.gov.tr/?p=3946

O'Toole, J. M., Freestone, M., McKoy, K. S., & Duckworth, B. (2018). Types, topics and trends: A ten-year review of research journals in science education. *Education Sciences, 8*(2), 73. https://doi.org/10.3390/educsci8020073

Okumuş, S., Doymuş, K. (2018). Modellerin okuma-yazma-uygulama yöntemi ve yedi ilke ile uygulanmasının maddenin tanecikli yapısı ve yoğunluk konularının kavramsal anlaşılmasına etkisi [The effect of using models with seven principles and cooperative learning on students' conceptual understandings]. *Abant İzzet Baysal University Education Faculty Journal*, *18*(3), 1603-1638.

Ornek, F. (2008). Models in science education: Applications of models in learning and teaching science. *International Journal of Environmental & Science Education, 3*(2), 35-45.

ISSN 1648–3898 /Print/
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Önder, N., Oktay, Ö., Eraslan, F., Gülçiçek, Ç., Göksu, V., Kanlı, U., Eryılmaz, A., & Güneş, B. (2013). Content analysis of physics education studies published in Turkish science education journal from 2004 to 2011. *Journal of Turkish Science Education, 10*(4), 151-163. http://tused.org/index.php/tused/article/view/403

Özkan, U. B. (2019). *Eğitim bilimleri araştırmaları için doküman inceleme yöntemi* [Document review method for educational sciences research]. Seçkin Publishing.

Paton, R. C. (1996). On an apparently simple modelling problem in biology. *International Journal of Science Education, 18*(1), 55-64. https://doi.org/10.1080/0950069960180105

Schwarz, C. (2009). Developing preservice elementary teachers' knowledge and practices through modeling-centered scientific inquiry. *Science Education, 93*(4), 720-744. https://doi.org/10.1002/sce.20324

Schwarz, C. V., & White, B. Y. (2005). Metamodeling knowledge: Developing students' understanding of scientific modeling. *Cognition and Instruction*, *23*(2), 165-205. https://doi.org/10.1207/s1532690xci2302_1

Schwarz, C. V., Reiser, B. J., Davis, E. A., Kenyon, L., Achér, A., Fortus, D., Shwartz, Y., Hug, B., & Krajcik, J. (2009). Developing a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for learners. *Journal of Research in Science Teaching, 46*(6), 632-654. https://doi.org/10.1002/tea.20311

Şeren, N., & Doğru, M. (2018). 4. sınıf öğrencilerinin fen bilimleri konularına yönelik zihinsel modelleri [The determination of mental models of 4th grade students on scientific subjects]. *Anatolian Journal of Teacher*, *2*(1), 19-34.

Sins, P. H., Savelsbergh, E. R., van Joolingen, W. R., & van Hout-Wolters, B. H. (2009). The relation between students' epistemological understanding of computer models and their cognitive processing on a modelling task. *International Journal of Science Education, 31*(9), 1205-1229. https://doi.org/10.1080/09500690802192181

Sözbilir, M., Kutu, H. & Yaşar, M.D. (2013). Status and trends in chemistry education research in Turkey. In M. Sözbilir (Ed). *Chemistry education in Turkey* (pp. 175-204). Turkish Chemical Society Publication.

Teo, T. W., Goh, M. T., & Yeo, L. W. (2014). Chemistry education research trends: 2004–2013. *Chemistry Education Research and Practice, 15*(4), 470-487. https://doi.org/10.1039/c4rp00104d

Treagust, D. F., Chittleborough, G., & Mamiala, T. L. (2002). Students' understanding of the role of scientific models in learning science. *International Journal of Science Education, 24*(4), 357-368. https://doi.org/10.1080/09500690110066485

Türk, C., & Kalkan, H. (2017). Modellerle astronomi öğretiminin öğrencilerin başarılarına ve tutumlarına etkisi [The effect of teaching astronomy with models on students' achievements and attitudes]. *Journal of Current Researches on Educational Studies*, *7*(2), 185-204.

Ulutaş, B., Üner, S., Turan-Oluk, N., Yalçın-Çelik, A., & Akkuş, H. (2015). Türkiye'deki kimya eğitimi makalelerinin incelenmesi: 2000-2013 [Analysis of chemistry education research papers in Turkey: 2000-2013]. *Journal of Kırşehir Education Faculty, 16*(2), 141-160.

Ünal, G., & Ergin, Ö. (2006). Fen eğitimi ve modeller [Science education and models]. *Milli Eğitim Dergisi, 171*, 188-196.

Van Driel, J. H., & Verloop, N. (1999). Teachers' knowledge of models and modelling in science. *International Journal of Science Education*, *21*(11), 1141-1153. https://doi.org/10.1080/095006999290110

Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of Curriculum Studies, 44*(3), 299-321. https://doi.org/10.1080/00220272.2012.668938

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science Education, 92*(5), 941-967. https://doi.org/10.1002/sce.20259

Yıldırım, A., & Şimşek, H. (2011). *Sosyal bilimlerde nitel araştırma yöntemleri (8.baskı)* [Qualitative research methods in the social sciences (8th Ed.)]. Seçkin Publishing.

Appendix 1

The Article analysis form (AAF)

Article Tag
Title
Author(s)
Year
Journal

Research Aim	Field/Topic
( ) To determine the effects of model or modelling-based teaching	( ) Biology / Topic:…….
( ) To examine mental models	( ) Physics / Topic:…….
( ) To examine the views on model or modelling-based teaching	( ) Chemistry / Topic:…….
( ) To examine the views on the nature of models and modelling	
( ) To examine process of modelling	
( ) *Other*	

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Research Method	Duration of Implementation
( ) Quantitative	( ) 1-3 weeks
( ) Qualitative	( ) 4-6 weeks
( ) Mixed	( ) 7-9 weeks
	( ) 10 weeks and above

Sample Group	Sample Size
( ) Postgraduate:….	( ) 1-30 persons
( ) Undergraduate Department/Program:….	( ) 31-60 persons
( ) High School/Grade:…..	( ) 61-90 persons
( ) Secondary School/Grade:……	( ) 91-120 persons
( ) Primary School/Grade:…….	( ) 121 persons and more
( ) Pre-school	
( ) Teacher / Lecturer	

Variable(s)	Data Collection Instrument
( ) Achievement Level	( ) Achievement Test
( ) Attitude	( ) Conceptual Understanding Test
( ) Level of Conceptual Understanding	( ) Document Analysis Rubric
( ) Mental Model	( ) Interview
( ) Misconceptions	( ) Questionnaire/Scale
( ) Modelling Competence	( ) Observation
( ) Participants' Views	( ) Skill Test
( ) Permanence of Learning	( ) *Other*
( ) *Other*	

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A SYSTEMATIC REVIEW OF THE RESEARCH PAPERS ON CHEMISTRY-FOCUSED SOCIO-SCIENTIFIC ISSUES

Muammer Çalık,
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Abstract. *Although chemistry-focused socio-scientific issues support the 'relevance' model of chemistry education, the related literature has lacked any systematic review handling them together. For this reason, this research aimed to thematically synthesize the research papers on chemistry-focused socio scientific issues (SSI) from 2008 to 2020 and inferentially evaluate them in terms of the relevance model of chemistry education. After searching international and national well-known databases through relevant keyword patterns (e.g., Pattern 1: socio-scientific issues and chemistry education), 65 research papers were apparent for the systematic review. Then, the authors generated primary and secondary codes for the research papers and then inferentially marked their 'relevance' components. The systematic review indicated variation of research areas (e.g., relevance model of chemistry education) and dominant research foci for different themes (e.g., competencies and related variables for the theme 'aims'; pollution, energy, industry and fabrication-based problems for the theme 'SSI'; organic compounds for the theme 'chemistry concepts'). Further, it revealed that the research papers on chemistry-focused SSI had some shortcomings at handling all components of the relevance model in a balanced way. The current research suggests professionally training teachers about how to integrate chemistry-focused SSI and the relevance model into school chemistry.*

Keywords: *chemistry education, relevance model, socio-scientific issues, systematic review*

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Introduction

Related literature has reported that science education, particularly physics and chemistry, remains unpopular among students (Avargil et al., 2020; Hofstein et al., 2011; Osborne & Dillon, 2008; Stuckey et al., 2013). Much research has also inferred that students are insufficiently interested in science learning. Phrased differently, science subjects do not motivate students to 'doing science' and 'learning of science' (Atasoy et al., 2020; Osborne et al., 2003; Stuckey et al., 2013). Unfortunately, students generally see science and science education as 'irrelevant' for themselves and society (Dillon, 2009; Gilbert, 2006; Stuckey et al., 2013). Therefore, science teachers should make education 'more relevant' in order to stimulate their students' interest in science subjects and/or science learning (Stuckey et al., 2013). Given the foregoing issues, Stuckey et al. (2013) have released the relevance model of science/chemistry education to make science learning relevant. Further, preliminary research papers on the relevance model have reported that socio-scientific issues (SSI) can be used to make science/chemistry learning more relevant (e.g., Eilks et al., 2018; Stuckey & Eilks, 2014; Zowada et al., 2020).

SSI typically contains disagreement and debate among experts, politicians, and citizens to decide the use of science and technology (Albe, 2008; Levinson, 2006; Sadler, 2004, 2009). Because SSI does not have a fixed or universally held point of view, SSI-related explanations and solutions often divide society into different groups (i.e., Crick, 1998; Çalik & Coll, 2012; Çalik et al., 2014). SSI incorporates contentious dilemmas (open-ended, complex, ill-structured issues) and cannot easily be addressed through recall of memorized content knowledge, or simple algorithms (Kolomuç & Çalık, 2019; Sadler, 2004, 2009; Tsai et al., 2019). Thereby, engaging students in SSI and science practices not only develops scientific/chemical literacy but also links societal issues with the nature of science and 21st century skills (Romine et al., 2016; Zeidler, 2015). Therefore, SSI-based instruction requires students to go beyond conceptual understanding (Feierabend & Eilks, 2011; Ke et al., 2020) and improves their critical thinking skills within an informed way or informal reasoning (Semilarski et al., 2019; Zeidler & Nichols, 2009).

Although SSI-based instruction, as an interdisciplinary and multidimensional approach, embraces several subjects (i.e., biology, chemistry,

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physics, earth sciences, environmental sciences and so forth), it generally employs a core subject (e.g., chemistry) to frame features and outcomes of student learning. Therefore, this research views chemistry as a focus of SSI (named chemistry-focused SSI) to cultivate chemical literacy and responsible citizenship. Thus, chemistry-focused SSI directly covers conceptual understanding of chemistry and chemical literacy for all students by linking school chemistry with daily life (i.e., Koçak Altundağ, 2018; Ültay & Çalik, 2012; Versprille et al., 2017) and any scientific, technological and environmental development (Gilbert & Treagust, 2009; Mozeika & Bilbokaite, 2010; Zahara & Atun, 2018). Because chemistry plays a milestone in addressing chemistry-focused SSI and finding alternative ways or solutions (Bertozzi et al., 2016; Seery, 2015), students are able to explore chemical problems using conceptual and procedural connections and judge social significance of chemistry on the community or daily life. For example, Eilks et al. (2018) used some chemistry-focused SSI (e.g., musk fragrances in shower gels, low-fat and low-carb diets, doping in professional and leisure sports, bioplastics, Stevia controversy, natural cosmetics, and tattooing) to inform students about responsible citizenship and scientific/chemical literacy. Handling SSI within school chemistry necessitates to learn chemistry concepts and perceive chemistry-related disciplines (e.g., biology, physics, earth sciences, environmental sciences). For example, if they comprehend fundamental acid-base concepts, they are able to critically think about acid rain and its possible effect(s) on the environment. Further, they are able to make an action on how to prevent acid rain. Overall, chemistry-focused SSI and relevance model of chemistry education propose to satisfy students' interest in chemistry and raise their learning motivation and attitudes towards chemistry/science (e.g., Eilks et al., 2018; Stuckey & Eilks, 2014; Stuckey et al., 2013). This, at hand, calls for a systematic review that thematically synthesizes the research papers on chemistry-focused SSI and evaluates them in terms of the relevance model of chemistry education. A lack of such a review paper emerges the need for the current research.

Research Problem

Given the significance of SSI in science education, a few review papers have discussed general trends, similarities and differences for decision making process and/or informal reasoning about SSI (Fang et al., 2019; Garrecht et al., 2018; Jho 2015; Sadler, 2004, 2009; Tekin et al., 2016; Topçu et al., 2014). They stressed that SSI acted as a milestone to make chemistry/science relevant and facilitate informal reasoning and decision-making processes. Of these review papers, only one research (Sadler, 2009) used situated learning as a theoretical framework to review and synthesize SSI as the context of practice. Sadler (2009) deployed situated learning as a powerful analytical lens to explain the influential role(s) of students' educative experiences on their lives. Phrased differently, the use of SSI requires science educators/teachers to re-think about the question "What makes school sciences relevant for students' present and future lives?" (e.g., Sadler, 2004, 2009; Stuckey et al., 2013). Even though SSI has a pivotal role at overcoming students' misperceptions of science education (e.g., lack of relevance) (Gilbert, 2006; Stuckey et al., 2013), none of previous review papers has focused on how the research papers on SSI reflect the relevance in science/chemistry education. In other words, they have not recruited the relevance model of chemistry education as a theoretical framework to analytically illuminate their similarities, differences, and trends.

Furthermore, even though the foregoing review papers have included few chemistry-related SSI (e.g., environmental issues or interdisciplinary problems), they have not directly concentrated on the research papers on chemistry-focused SSI (i.e., road salting, doping in professional and leisure sports, and tattooing) and the 'relevance' model of chemistry education. The gap in related literature calls for the current research to portray the characteristics of chemistry-focused SSI. Hence, the current research may give some insights into chemistry-focused SSI by evaluating the research papers through 'relevance' model of chemistry education (Stuckey et al., 2013). In brief, this research thematically illustrates what is known and what needs to be known for future research on chemistry-focused SSI.

Research Focus

Over 40 years, science educators have argued how to make science education relevant and appeal for students. These debates have resulted in science curriculum reforms and/or movements prioritizing the term 'relevance' in science education (Fensham, 2004; Stuckey et al., 2013). A comprehensive literature review by Stuckey et al. (2013) suggests that making science education 'relevant' at least includes three dimensions: (a) preparing students for

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potential careers in science and engineering; (b) understanding scientific phenomena and coping with the challenges in a student's life; and (c) students becoming effective future citizens in the society in which they live (p. 8). Given all issues reported in science education literature, Stuckey et al. (2013) have launched their own model to clarify the term 'relevance' in science education.

The relevance model of chemistry education consists of three dimensions (individual, societal and vocational) and four components (present, future, intrinsic and extrinsic) for each dimension (see Stuckey et al., 2013 for further details and examples). In view of Stuckey et al. (2013), the relevance model develops students' intellectual skills and competencies, awareness and understanding of individual, societal and vocational dimensions (Stuckey et al., 2013). Furthermore, the model highlights two principal questions debated by science educators: (a) how does science education make school science learning relevant for students' present and future lives? and (b) How is school science learning connected to students' out-of-school experiences?

The 'relevance' model can also be used to analyze different curricula (e.g., Salters Advanced Chemistry in the UK) or reforms (e.g., context-based learning) or movements (e.g., SSI). That is, the question "how does any curriculum/reform/movement refer to the 'relevance' model?" may help science educators and curriculum developers decide any new curricular development. Indeed, science educators have recently employed various SSI to respond the foregoing questions and present alternative pedagogical ways to make science learning more relevant. However, none of previous research papers has concentrated on how the research papers on chemistry-focused SSI have supported the relevance model. Further, they have not explored whether there has been any balanced way in promoting different dimensions of the relevance model. These unexplored areas in the related literature emerge the needs of the current research.

Research Significance

Chemistry/science educators have used chemistry-focused SSI to increase learning opportunities and associate school chemistry with societal and real issues (Stuckey et al., 2013). By evaluating the research papers via the 'relevance' model of chemistry education, this research will give some clues about how to make chemistry relevant and popular among students. Hence, the current research will inform chemistry educators, teachers and curriculum developers about trends and unexplored areas in chemistry-focused SSI. Also, handling the research papers within themes (i.e., aims, samples, variables, SSI, dimensions of SSI, chemistry concepts and conclusions) will present a holistic view to unveil their insights and changes over years. Overall, filling an important gap in the related literature makes the current research unique and significant.

Research Aim and Research Questions

This research purposed to thematically synthesize the research papers on chemistry-focused SSI from 2008 to 2020 and inferentially evaluate them in terms of the relevance model of chemistry education. For this purpose, the following research questions guided the current research:

1. What thematic codes do the papers show?
2. How do the papers reflect the relevance model of chemistry education?

Research Methodology

General Background

This research critically and systematically synthesized the research papers on chemistry-focused SSI by creating themes and template (e.g., Bağ & Çalık, 2017; Çalık & Sözbilir, 2014). Thus, it purposed to indicate general trends, similarities and differences of chemistry-focused SSI to disseminate research results and inform stakeholders about further research, policy and practice (Suri & Clarke, 2009) (see Figure 1 for the systematic review procedure).

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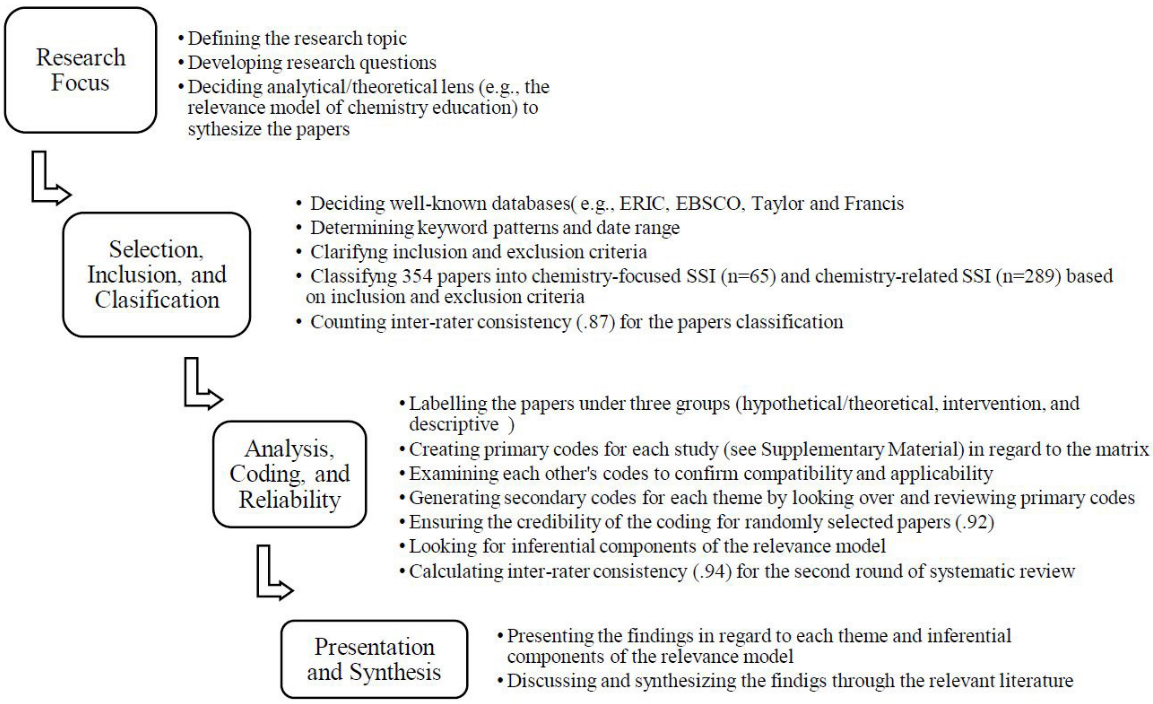
Figure 1
An Outline of the Systematic Review Procedure



Data Collection

The authors searched international and national well-known databases (Academic Search Complete, Education Research Complete, ERIC, EBSCO, Springer Link, Taylor & Francis, Wiley Online Library Full Collection, Science Direct, ProQuest Dissertations and Theses Global, Sage Premier 2013, Google Scholar, Scopus, Academia, ResearchGate and e-resources) by means of relevant keyword patterns (Pattern 1: "socio-scientific issues" and "chemistry education"; Pattern 2: "socio-scientific issues" and "science education"; Pattern 3: "controversial issues" and "science education"; Pattern 4: "societal issues" and "science education"; Pattern 5: "daily life" and "chemistry education"; and Pattern 6: "chemical literacy" and "chemistry education") within a certain date range (2008 to 2019) and completed the regular database search on January 25, 2020 (*n*: 325). Further, the authors conducted another database search on December 15, 2020 to cover the research papers (*n*: 29) published in 2020. Then, the authors assigned specific identities (i.e., short titles and authors' names) for each research to refrain from any duplication in databases. Later, given the foci of the current research, 354 research papers were separately classified into chemistry-focused SSI (*n*: 65) and chemistry-related SSI (i.e., interdisciplinary problems/issues) (*n*: 289). In this process, their abstracts were initially read to label them as chemistry-focused/related SSI. When any disagreement or conflict appeared at the classification process, the research papers were deeply examined in regard to inclusion and exclusion criteria.

The authors deployed four criteria for inclusion of chemistry-focused SSI: (1) directly employing chemistry as a driving factor for SSI; (2) handling SSI within any chemistry-focused course(s) or chemistry topic(s) in an integrated science course(s) or science laboratory course(s) or Science, Technology, Engineering, and Mathematics (STEM) education; (3) prioritizing the importance of chemistry in daily life through scientific/chemical literacy; and (4) associating chemistry concepts with other related disciplines or concepts. For example, Çalik and Cobern (2017), who directly exploited 'factors affecting solubility' within the Introductory Chemistry Course, prioritized the importance of chemistry in daily life, i.e., road salting, and associated chemistry with environmental chemistry, environmental education, and ecology. Hence, the authors included this research into the systematic review. In

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contrast, the authors excluded the research by Çalik and Coll (2012), which indirectly handled chemistry within global warming and the use of fluoride in municipal water or preceded interdisciplinary issues/problems. Finally, 65 research papers were of interest in the current research (see Appendices at Supplementary Material).

Data Analysis

While grouping the papers as chemistry-related/focused SSI, the authors noticed three research types (*hypothetical/theoretical* research that illustrates any chemistry-focused SSI without any implementation or discusses a sample theoretical framework via the existing literature; *intervention* research that includes the experimental design and/or treatment; and *descriptive* research that explores the participants' views, values, argumentation skills, understanding, perceptions and decision-making processes as well as evaluating lesson plans and/or learning outcomes of chemistry-focused SSI). Thereby, the authors initially labelled the research papers into three groups (i.e., hypothetical/theoretical, intervention and descriptive). To present a detailed and comprehensive systematic review, the authors adapted a matrix (e.g., aims, variables, samples/participants, chemistry concepts, SSI, dimensions of SSI and conclusions) proposed by Çalik et al. (2005). Later, they created primary codes for each research (see Supplementary Material) in regard to the matrix and examined each other's codes to confirm their compatibility and applicability. Then, they generated secondary codes for each theme by inductively reviewing primary codes. Hence, general trends, similarities, differences, and unique features of the research papers were obviously apparent. Moreover, the authors inferentially marked the 'relevance' components of the research papers by carefully re-examining them (see Table S1 for a sample review).

Research Validity and Reliability

To minimize any missing data, two chemistry educators separately classified 354 research papers into two groups (i.e., chemistry-focused SSI and chemistry-related SSI). Inter-rater consistency was found to be .87. Any disagreement was resolved through negotiation. Also, a group of experts (authors and two chemistry educators) independently coded four research papers randomly selected from 65 research papers to ensure the credibility of the coding. Accordingly, inter-rater consistency was found to be .92, which suggests a perfect agreement for the coding (MacPhail et al. 2015; Miles & Huberman, 1994). Later, the authors individually continued the coding procedure and created primary codes for each research (see Supplementary Material). Then, they generated secondary codes by inductively reviewing primary ones. In addition, the authors looked over each other's codes and confirmed their compatibility and applicability. Furthermore, they separately searched the 'relevance' components in the research papers and then checked each other's relevance components. This procedure showed a high consistency value (.94).

Research Results

Thematic Codes for the Research Papers

Theme 'Aims'. As seen from Table S2 (see Supplementary Material), the aims of the research papers consisted of five different codes, whose percentages ranged from 4.6 to 38.5. A high frequency for the first code (see Table S2) may result from common features of SSI that directly trigger or influence such competencies as argumentation, reflective judgment, decision making, and informal reasoning (e.g., Bayram-Jacobs et al., 2019; Karışan et al., 2017; Wiyarsi & Çalik, 2019). The second code may come from mostly preferred common variables, i.e., conceptual understanding, attitude, critical thinking (e.g., Çalık et al., 2015). These papers seem to have provided more evidence about the effect(s) of chemistry-focused SSI on the quality of chemistry education.

The third and fourth codes, which integrated chemistry-focused SSI into chemistry learning/school chemistry, seem to have stimulated students' enthusiasm and interest in chemistry (e.g., Gilbert, 2006; Ilhan et al., 2016; Ültay & Çalik, 2012). In fact, these codes also point to responsible citizens in the future (called scientific or chemical literacy). However, the final code (developing measurement tools/instruments regarding chemistry-focused SSI) indicated a challenge to effectively measure and assess their use in chemistry learning. This calls for further research to elicit students' learning curiosity, interest in science/chemistry, higher-order thinking skills and relevant competencies. In a similar vein, orientating participants about potential chemistry/science/STEM careers in their present and future actions can only be accomplished via reliable and valid tools (Stuckey et al., 2013).

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Theme 'Variables'. As can be seen from Table S3, independent variables covered various teaching interventions (i.e., inquiry-based learning, common knowledge construction model, context-based approach). Also, their dependent variables were varied such as conceptual understanding (*f*=4), critical thinking (*f*=3), environmental literacy (*f*=3), perception/expectation (*f*=3), and attitudes (*f*=3). In brief, dependent variables embraced 'reasoning skills or higher-order thinking skills' (*f*: 13) (e.g., critical thinking, environmental literacy, decision making, argumentation, and chemical/scientific literacy) and affective learning domain(s) (*f*: 11) (e.g., attitude, perception, motivation, self-efficacy and scientific habits of mind). Also, most of them were classified under 'not applicable' since they did not have any independent/dependent variable.

As can be seen from Table S3 (see Supplementary Material), 23 research papers deployed any teaching intervention as an independent variable. Through hands-on and minds-on activities/tasks, they encouraged participants to re-construct their pre-existing knowledge or stimulate their attitudes, interest, perceptions and self-efficacy or informal reasoning skills or argumentation skills (as dependent variables) (e.g., Abels, 2015; Çalik & Cobern, 2017; NRC, 2000). Thus, they may have tried to meet the idea 'education through science' vis-à-vis the one 'education in science' (e.g., Holbrook & Rannikmae, 2007). In other words, constructivist learning theory seems to have affected independent variables (e.g., inquiry-based learning, context-based approach, learning cycle, cooperative learning).

Since most of the dependent variables covered transferable and transformable skills (e.g., critical thinking, environmental literacy, decision making, argumentation, and chemical literacy), the research papers seem to have paid more attention to the demands of the 21st century skills. Meanwhile, although they concentrated on cognitive and affective learning domains (e.g., conceptual understanding, environmental/chemical literacy, attitude, perception, motivation, self-efficacy, and scientific habits of mind) as dependent variables, they have not focused on psychomotor skills that enables students to comprehend the nature and philosophy of science/chemistry (e.g., Irwanto et al., 2019; Karsli Baydere et al., 2020). Interestingly, only one each paper explicitly focused on chemical literacy (Cigdemoglu & Geban, 2015) and scientific literacy (Vogelzan et al., 2020) as a dependent variable. This may result from the scope of scientific literacy (i.e., conceptual understanding, nature of science, scientific habits of mind, scientific attitudes, awareness of the complex relationship(s) among science, technology, society, and environment). Namely, most of the intervention papers seem to have focused on various dimensions of scientific literacy instead of explicitly exploring the effect of any treatment on chemical/scientific literacy level (Roberts & Bybee, 2014; Zeidler, 2015).

Theme 'Samples'. As seen from Table S4 (see Supplementary Material), almost half of the research papers selected their participants from 6th-13th grades. A total of 25 (37.9%) research papers involved undergraduate students, while 4 (6.1%) research papers included teachers in their samples. Only one paper (Molinatti & Simonneau, 2015) used scientists as its sample.

The fact that majority of the research papers were conducted with 6th -13th grade students (see Table S4) may stem from a common belief 'lower and upper secondary schools shape students' individual, societal and vocational development.' Further, since undergraduate education and qualified teachers play a pivotal role in chemistry learning/teaching, a significant amount of the research papers may have studied with undergraduate students and teachers (Wan et al., 2013; Karisan et al., 2017). In fact, qualified teachers give much more learning opportunities for their students to empower their learning capacities. For instance, if teachers have relevant competencies/experiences concerning chemistry-focused SSI, they are able to effectively understand and interpret chemistry curriculum and its goals. Thus, such a procedure not only facilitates students' chemistry learning but also promotes chemistry self-efficacy and self-regulated skills for the present and future. Furthermore, the fact that only one paper (Molinatti & Simonneau, 2015) involved scientists as the sample may come from scientists' unwillingness to participate in any research on chemistry-focused SSI. On the other hand, the belief 'scientists always have good reasoning/rational skills or give scientific arguments about chemistry-focused SSI' may have led chemistry/science educators not to study with scientists.

Theme 'SSI'. As can be seen from Table S5 (see Supplementary Material), ten codes appeared for the theme 'SSI.' Twenty-one research papers focused on chemicals and environmental pollution, while 20 research papers concentrated on the use of fossil fuels. Further, percentages of the codes 'chemicals in daily life, alternative energy sources, and nutrition' were 11.7, 10.6 and 10.6 respectively, whereas those for the codes 'addictive, food additive, abuse of chemical substances, and chemical in medicine' were 8.5, 4.3, 3.2, and 3.2 respectively.

Although chemistry positively enhances quality of daily life, it engenders some risks. For this reason, the research papers exploited various SSI to make science/chemistry more relevant for their participants. For example, the code 'the use of fossil fuels' might help participants think about how to reduce the effect(s) of global warming.

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That is, they might prefer using public transportation or bicycle while going to the school.

The code 'chemicals and environmental pollution' might bridge school science/chemistry to daily life (e.g., Albe, 2008; Holbrook, 1998; Flener-Lovitt, 2014; Versprille et al., 2017) and stimulate participants' interest and attitudes towards chemistry (e.g., Versprille et al., 2017) as well as developing their problem-solving strategies (Mandler et al., 2012). The code 'alternative energy sources' might encourage participants to re-think our consumption habits. Hence, people could think about evidence and content knowledge (e.g., Flener-Lovitt, 2014; Yapıcıoğlu & Aycan, 2018; Karpudewan & Roth, 2016) by weighing and leveraging dimensions of SSI such as economic, environmental, health, social and ethics (Price et al., 2014).

Since daily chemical products may unwittingly endanger human life, the research papers used the code 'chemicals in daily products (i.e., cosmetics, tattooing, soap, shower gels and musk fragrances)' as another interesting SSI. For example, tattoos bring their own risks, e.g., carcinogenic compounds in tattoos (Regensburger et al., 2010), the lack of acceptance in society, tattooing equipment and removing process of tattoos (Stuckey & Eilks, 2014). Risks and benefits of any chemistry-focused SSI require participants to employ critical thinking and argumentation skills (Sadler, 2004; Zeidler & Nichols, 2009). Thus, they can improve open-mindedness and multidimensional thinking while making a decision about any chemistry-focused SSI. Overall, integrating SSI into chemistry learning not only empowers participants' cognitive and affective learning outcomes but also creates a meaningful learning environment. This indicates that chemistry-focused SSI supports informal and formal reasoning abilities without confining chemistry to schools (e.g., Ültay & Çalik, 2012, 2016; Wiyarsi et al., 2020).

Theme 'Chemistry Concepts'. As can be seen from Table S6 (see Supplementary Material), the research papers used chemistry concepts such as organic compounds, macromolecules, inorganic compounds, colloid, acids-bases, and surfactant. Majority of them focused on the organic compounds (e.g., hydrocarbon, amine, alcohol, and ester) through the relevant SSI. Percentages of the research papers handling macromolecules and inorganic compounds were 14.3 and 13.3 respectively, whilst those for the codes 'acids-bases, colloid, thermodynamics, surfactant, and solubility' ranged from 5.7 to 2.9. Also, percentages of the remaining codes fell into 1.9 and 1.0 respectively.

Because organic compounds are mostly used in daily products, the use of organic compounds might be viewed as easily accessible and applicable for chemistry-focused SSI. In addition, the fact that 15 research papers employed macromolecules within chemistry-focused SSI may come from their nutrition and health relations (e.g., fats and carbohydrates). For example, polymers, which are highly economic vis-à-vis natural products, may result in environmental (i.e., a long dissolving period in nature) and health (e.g., cancer) risks. Likewise, main environmental concerns may have directed chemistry/science educators to use other chemistry concepts within chemistry-focused SSI.

The variation in chemistry concepts may come from the nature of chemistry topics. That is, some topics include much more ill-structured, open-ended, and complex issues that call for directly and indirectly relevant chemistry concepts (e.g., organic compounds, macromolecules, inorganic compounds). However, some of them only contain an SSI for relevant chemistry concepts (e.g., solubility for road salting, acids for acid rain). In brief, the research papers seem to have created 'a need-to-know' basis to make abstract chemistry concepts meaningful and emphasize daily-life relevance (e.g., Ültay & Çalik, 2012, 2016; Wiyarsi et al., 2020).

Theme 'Dimensions of SSI'. As seen from Table S7 (see Supplementary Material), nine codes were apparent for this theme. A significant number of the research papers covered societal (23.7%), environmental (23.7%), economic (20.1%) and health (16.0%) dimensions of chemistry-focused SSI. Further, percentages of technological and ethical dimensions fell into 8.8 and 4.1 respectively, whereas those for moral, political, and religious dimensions ranged from 0.5 to 1.5.

Five dominant codes (societal, environmental, economic, health and technological) may result from features of chemistry-focused SSI. For example, biofuel crops (e.g., castor bean, cassava, and corn), which incorporate societal, environmental, economic, and technological dimensions, engage participants in thinking about the need of new agricultural lands. Further, because people with middle and lower incomes mostly struggle with economic issues (e.g., budget, extra cost), they may prioritize economic dimension for their decision-making processes. For example, they may prefer cheap chemicals (e.g., sodium chloride) in snow removal to expensive alternative chemicals. Even though SSI broadly stresses ethics, moral reasoning and emotional development, few research papers handled these dimensions within chemistry-focused SSI. In a similar vein, only one paper (Rahem, 2018) examined religious dimension through the medical use of alcohol (permissibility or 'halal'-ness). This may stem from dogmatic feature of religion. Likewise, the fact that only three papers (Pratiwi et al., 2016; Stuckey & Eilks 2014; Gulacar et al., 2020) focused on the political dimension may come from a belief 'political issues cannot be easily changed, or politicians are not easily accessible.'

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Theme 'Conclusions'. As seen from Table S8 (see Supplementary Material), four different codes appeared. Most of the research papers fell into the first two codes: Fruitfulness of chemistry-focused SSI to explore related competencies/factors (41.5%) and positive improvement/change in learning outcomes (35.4%). Further, percentages of the remaining codes were 18.5 and 4.6 respectively.

As seen from Table S8, two-fifth of them concluded that chemistry-focused SSI was fruitful to explore related competencies/factors (e.g., argumentation skills, decision making skills). Hence, chemistry-focused SSI allows participants to possess multidimensional thinking skills (Acar et al., 2010; Cavagnetto, 2010; Evagorou & Osborne, 2013; Sadler, 2004, 2009) and behave as responsible citizens (Çapkınoğlu & Yilmaz, 2018; Stuckey et al., 2013). Moreover, positive improvements/changes in chemistry learning (e.g., critical thinking skills, argumentation skills, scientific literacy) may come from student-centered approaches/strategies (i.e., inquiry-based learning, leaning cycles, experimental scientific practices) in chemistry classes (Aydeniz et al., 2012; Herrenkohl & Cornelius, 2013; Memiş, 2014).

Twelve research papers, which reported good learning practices or measurement tools (i.e., lesson plans, instruments), illustrated why the use of chemistry-focused SSI was important for chemistry learning/classes. Thereby, given these good learning practices or measurement tools, chemistry teachers/educators may get some insights about the question 'how to handle chemistry-focused SSI within chemistry learning/school chemistry.' Interestingly, only three research papers (Eilks et al., 2018; Juntunen & Aksela, 2014; Marks & Eilks, 2009) explicitly associated chemistry-focused SSI to other aspects or disciplines (e.g., ESD and curriculum model). This may result from complex nature of interdisciplinary research (e.g., finding enough budget, working with different experts, and intertwining different content knowledge/disciplines with chemistry). On the other hand, this may come from the focus of the current research, which excluded chemistry-related SSI emphasizing interdisciplinary problems/issues.

Inferential Components for the Relevance Model of Chemistry Education

As seen from Table S9, all of the research papers referred to the future-intrinsic and extrinsic components of individual and societal dimensions. This may result from the goal of chemistry education, which is to educate students to become a responsible citizen in the future. Further, this may come from features of chemistry-focused SSI that confront students with ill-structured issues and drive them to use their own transferable and transformable skills. These skills/competencies not only facilitate their individual lives in future to solve real-world problems (the future-intrinsic component of individual dimension) (Stuckey et al., 2013), but also promote their own interest in societal discourse (the future-intrinsic component of societal dimension). Because chemistry-focused SSI also advocates multidimensional thinking and scientific habits of mind (i.e., open-mindedness, skepticism), it employs skills for coping with personal life in the future and activates participants' responsibilities and solidarities with others (the future-extrinsic component of individual dimension). Further, it cultivates them to behave as responsible citizens in the society (the future-extrinsic component of societal dimension) (Stuckey et al., 2013).

Most of the research papers handled the present-intrinsic component of individual dimension (*f*: 62; 95.4%) and present-intrinsic and extrinsic components of societal dimension (*f*: 54; 83.1%). A high proportion in the present-intrinsic component of individual dimension may stem from a 'need-to-know' basis (e.g., Ültay & Çalik, 2012), which individually satisfies students' learning curiosity and stimulates their interest in chemistry/science (Stuckey et al., 2013). In other words, because SSI acts as an actual context to see the relevance of chemistry in daily life (Flener-Lovitt, 2014; Gilbert, 2006; Parchmann et al., 2006), the research papers may have purposed to equip the participants with personal and societal life skills (Feierabend & Eilks, 2011; Stuckey et al., 2013) and meet their individual learning curiosity/interest in the present. Likewise, through the present-intrinsic and extrinsic components of societal dimension, the research papers seem to have promoted the participants to find their own places in society (e.g., becoming a scientifically literate person) and learn how to behave in society (Stuckey et al., 2013). For example, students are able to defend their own decisions/arguments about any regulation of the use of shale gas (Bayram et al., 2019; Mollinati & Simmoneu, 2015). Their arguments/decisions may lead them to find their own places in society and learn how to defend their own views of chemistry-focused SSI (Stuckey et al., 2013).

The research papers generally dealt with the present-intrinsic and extrinsic components of vocational dimension. In fact, these ratios were relatively low as compared to other dimensions of the relevance model. This means that the research papers have had some difficulties at embedding vocational dimension and related components within science/chemistry learning. Given all components of vocational dimension, the research papers reflected the present-intrinsic and extrinsic components rather than the future ones. This may result from the nature of the

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present components of vocational dimension. That is, the researchers may have found these components more applicable and researchable than the future-ones. Indeed, the future components of vocational dimension generally request a long-term research to examine the targeted/expected goals. Moreover, any research, which recruits any regular course (e.g., introductory chemistry course) (Çalik & Cobern, 2017), extrinsically fosters participants' advanced science learning and enhances the quality of their next education. Thus, the research papers may have illuminated the present-extrinsic component of vocational dimension. Similarly, the research papers exploring good practices for science/chemistry learning may have stimulated participants' orientation about potential chemistry/science/STEM careers (the present-intrinsic component of vocational dimension) (Stuckey et al., 2013). For instance, using acid rain as an SSI may foster participants to learn how chemists or chemistry-related occupations can minimize the impact(s) of acid rain on chlorosis/corrosion and acidity of ocean. Indeed, if participants feel themselves comfortable for chemistry learning and achieve the targeted goals of chemistry education, they are able to continue their chemistry careers.

The present-extrinsic component of individual dimension, which possessed the lowest percentage, maybe a result of any research concern. For instance, the use of extra marks and/or credits (as the present-extrinsic component of individual dimension) may extrinsically manipulate the research results. Therefore, the researchers may have disregarded this component in their papers. Nevertheless, the foregoing results may come from limited research directly following the relevance model of chemistry education.

Conclusions and Implications

The systematic review indicated variation of research areas (e.g., relevance model of chemistry education) and dominant research foci with different themes (e.g., competencies and related variables for the theme 'aims'; students (6th-13th grades) and undergraduate students for the theme 'samples'; pollution, energy, industry and fabrication-based problems for the theme 'SSI'; organic compounds for the theme 'chemistry concepts'). As compared with earlier review papers, the current research showed that chemistry/science educators preferred more chemistry-focused SSI over time. This means that chemistry-focused SSI has invaluable learning opportunities to make chemistry learning and chemical literacy sustainable. Since the research papers reported promising results/conclusions about associating school chemistry with societal/real-life issues, the current research justified the significance of the 'relevance' model at developing responsible citizenship and increasing students' interest in learning chemistry. However, the research papers somewhat illuminated individual (e.g., satisfying curiosity and interest in the present, and skills for coping with personal life in the future), societal (e.g., behaving as a responsible citizen, and promoting one's own interest in societal discourse in the future) and vocational (e.g., orientation about potential careers in the present) dimensions of the relevance model. Given these results, it can be concluded that they have still had some shortcomings at reflecting and supporting all components of the relevance model in a balanced way. For this reason, future research should make more emphasis on the future components of the relevance model (e.g., the future-intrinsic and extrinsic components of vocational dimension). Moreover, further research ought to illustrate how to integrate all components of the 'relevance' model into school chemistry in a balanced way.

Because chemistry-focused SSI has a pivotal role at developing the 21st century skills, future research should measure and explore its impacts on chemistry learning and/or chemistry careers. Further research should also focus on psychomotor skills that play a significant role in chemistry learning. Moreover, given widespread use of educational technologies, future research ought to improve technology-integrated instructions/interventions for chemistry-focused SSI and test their possible effects on learning outcomes. Furthermore, reliable and valid tools should be developed to predict participants' orientation about potential chemistry/science/STEM careers. Given little research discovering scientists' views of chemistry-focused SSI, further research should focus on their views, attitudes, perceptions, and arguments of ill-structured and open-ended issues. Moreover, because teachers act as the principal factor to achieve the goals of chemistry learning, future research ought to professionally train them about how to integrate chemistry-focused SSI and the relevance model into school chemistry. For example, teachers may be educated about creating their own concept cartoons of chemistry-focused SSI.

Research Limitations

Even though SSI, as an interdisciplinary and multidimensional approach, covers chemistry, biology, earth sciences and so on, this research only focused on the research papers on chemistry-focused SSI. Hence, review-

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ing chemistry-focused SSI may be seen as the first limitation of the research. Also, refining the research papers within the period of 2008-2020 (as the recency criterion) may be viewed as the second limitation of the current research. Given the word limit of the journal, the current research, as part of an extensive international project, only reported some themes and excluded the research papers on chemistry-related SSI. This may be considered as the third limitation of the research.

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Declaration of Interest

Authors declare no competing interest.

Supplementary Material

Please visit the link https://www.researchgate.net/publication/350735272_JBSE_SM for all tables and appendices.

References

Abels, S. (2015). Scaffolding inquiry-based science and chemistry education in inclusive classrooms. In N. L. Yates (Ed.), *New development in science education research* (pp. 77-96). Nova Science Publisher.

Acar, O., Turkmen, L., & Roychoudhury, A. (2010). Student difficulties in socio-scientific argumentation and decision-making research findings: Crossing the borders of two research lines. *International Journal of Science Education*, *32*(9), 1191–1206. https://doi.org/10.1080/09500690902991805

Albe, V. (2008). Students' positions and considerations of scientific evidence about a controversial socioscientific issue. *Science and Education, 17*(8–9), 805-827. https://doi.org/10.1007/s11191-007-9086-6

Atasoy, S., Eryılmaz Toksoy, S., & Çalık, M. (2020). Identifying pre-service teachers' initial impressions of the concept cartoons in the school corridors and informal physics learning. *Journal of Baltic Science Education, 19*(1), 25-35. https://doi.org/10.33225/jbse/20.19.25

Avargil, S., Kohen, Z., & Dori, Y.J. (2020). Trends and perceptions of choosing chemistry as a major and a career. *Chemistry Education: Research and Practice, 21*(2), 668-684. https://doi.org/10.1039/c9rp00158a

Aydeniz, M., Pabuccu, A., Çetin, P. S., & Kaya, E. (2012). Argumentation and students' conceptual understanding of properties and behaviors of gases. *International Journal of Science and Mathematics Education, 10*, 1303–1324. https://doi.org/10.1007/s10763-012-9336-1

Bağ, H., & Çalık, M. (2017). A thematic review of argumentation studies at the K-8 level. *Education and Science, 42*(190), 281-303. http://dx.doi.org/10.15390/EB.2017.6845

Bayram-Jacobs, D., Wieske, G., & Henze, I. (2019). A chemistry lesson for citizenship: Students' use of different perspectives in decision-making about the use and sale of laughing gas. *Education Sciences*, *9*(2), 1–16. https://doi.org/10.3390/educsci9020100

Bertozzi, C. R., Chang, C. J., Davis, B. G., Olvera de la Cruz, M., Tirrell, D. A., & Zhao, D. (2016). *Grand Challenges in Chemistry for 2016 and Beyond. ACS Central Science, 2*(1), 1–3. https://doi.org/10.1021/acscentsci.6b00010

Çalik, M., Ayas, A., & Ebenezer, J. V. (2005). A review of solution chemistry studies: Insights into students' conceptions. *Journal of Science Education and Technology, 14*(1), 29–50. https://doi.org/10.1007/s10956-005-2732-3

Çalik, M., & Cobern, W. W. (2017). A cross-cultural study of CKCM efficacy in an undergraduate chemistry classroom. *Chemistry Education Research and Practice, 18*(4), 691–709. https://doi.org/10.1039/c7rp00016b

Çalik, M., & Coll, R. (2012). Investigating socio-scientific issues via scientific habits of mind: Development and validation of the scientific habits of mind survey. *International Journal of Science Education, 34*(12), 1909–1930. https://doi.org/10.1080/09500693.2012.685197

Çalık, M., & Sözbilir, M. (2014). The parameters of the content analysis. *Education and Science, 39*(174), 33–38. https://doi.org/10.15390/EB.2014.3412

Çalik, M., Turan, B., & Coll, R.K. (2014). A cross-age study of elementary student teachers' scientific habits of mind concerning socioscientific issues. *International Journal of Science and Mathematics Education, 12*(6), 1315–1340. https://doi.org/10.1007/s10763-013-9458-0

Çalık, M., Ültay, N., Kolomuç, A., & Aytar, A. (2015). A cross-age study of science student teachers' chemistry attitudes. *Chemistry Education: Research and Practice, 16*(2), 228-236. https://doi.org/10.1039/c4rp00133h

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Çapkınoğlu, E., & Yılmaz, S. (2018). Examining the data component used by seventh grade students in arguments related to local socio-scientific issues. *Education and Science, 43*(196), 125–149. http://dx.doi.org/10.15390/EB.2018.7205

Cavagnetto, A. R. (2010). Argument to foster scientific literacy: A review of argument interventions in K-12 science contexts. *Review of Educational Research*, *80*(3), 336–371. https://doi: 10.3102/0034654310376953

Cigdemoglu, C., & Geban, O. (2015). Improving students' chemical literacy levels on thermochemical and thermodynamics concepts through a context-based approach. *Chemistry Education Research and Practice, 16*(2), 302–317. https://doi.org/10.1039/c5rp00007f

Crick, B. (1998). *Education for citizenship and the teaching of democracy in schools*. Qualifications and Curriculum Authority.

Dillon, J. (2009). On scientific literacy and curriculum reform. *International Journal of Environmental & Science Education, 4*, 201–213.

Eilks, I., Marks, R., & Stuckey, M. (2018). Socio-scientific issues as contexts for relevant education and a case on tattooing in chemistry teaching. *Education Quimica, 29*(1), 9–20. http://doi.org/10.22201/fq.18708404e.2018.1.63680

Evagorou, M., & Osborne, J. (2013). Exploring young students' collaborative argumentation within a socioscientific issue. *Journal of Research in Science Teaching*, *50*(2), 209–237. http://doi.org/10.1002/tea.21076.

Fang, S. C., Hsu, Y. S., & Lin, S. S. (2019). Conceptualizing socio-scientific decision making from a review of research in science education. *International Journal of Science and Mathematics Education, 17*(3), 427–448. https://doi.org/10.1007/s10763-018-9890-2

Feierabend, T., & Eilks, I. (2011). Teaching the societal dimension of chemistry using a socio-critical and problem-oriented lesson plan based on bioethanol usage. *Journal of Chemical Education, 88*(9), 1250–1256. https:// doi.org/10.1021/ed1009706

Flener-Lovitt, C. (2014). Using the socio-scientific context of climate change to teach chemical content and the nature of science. *Journal of Chemical Education*, *91*(10), 1587-1593. http://dx.doi.org/10.1021/ed4006985.

Garrecht, C., Bruckermann, T. & Harms, U. (2018). Students' decision-making in education for sustainability-related extracurricular activities—A systematic review of empirical studies. *Sustainability, 10*(3876), 1–19. https://doi.org/10.3390/su10113876

Gilbert J. K., & Treagust, D. F. (2009). *Macro, submicro and symbolic representations and the relationship between them: Key models in chemical education, multiple representations in chemical education*. Springer Netherlands.

Gilbert, J. (2006). On the nature of 'context' in chemical education. *International Journal of Science Education, 28*(9), 957–976. https://doi.org/10.1080/09500690600702470

Gulacar, O., Zowada, C., Burke, S., Nabavizadeh, A., & Bernardo, A., & Eilks, I. (2020). Integration of a sustainability-oriented socio-scientific issue into the general chemistry curriculum: Examining the effects on student motivation and self-efficacy. *Sustainable Chemistry and Pharmacy*, *15*(100232), 1-8. https://doi.org/10.1016/j.scp.2020.100232

Herrenkohl, L. R., & Cornelius, L. (2013). Investigating elementary students' scientific and historical argumentation. *The Journal of the Learning Sciences, 22*, 413–461. https://doi.org/10.1080/10508406.2013.799475

Hofstein, A., Eilks, I., & Bybee, R. (2011). Societal issues and their importance for contemporary science education: A pedagogical justification and the state of the art in Israel, Germany, and the USA. *International Journal of Science and Mathematics Education, 9*, 1459–1483. https://doi.org/10.1007/s10763-010-9273-9.

Holbrook, J. (1998). Operationalising scientific and technological literacy: A new approach to science teaching. *Science Education International*, *9*, 13–18.

Holbrook, J., & Rannikmae, M. (2007). The nature of science education for enhancing scientific literacy. *International Journal of Science Education, 29*(11), 1347–1362. https://doi.org/10.1080/09500690601007549

Ilhan, N., Yildirim, A., & Yilmaz, S. D. (2016). The effect of context-based chemical equilibrium on grade 11 students' learning, motivation, and constructivist learning environment. *International Journal of Environmental & Science Education, 11*(9), 3117–3137. https://doi.org/10.12973/ijese.2016.919a

Irwanto, I., Rohaeti, E., & Prodjosantoso, A. K. (2019). Analyzing the relationships between pre-service chemistry teachers' science process skills and critical thinking skills. *Journal of Turkish Science Education, 16*(3), 299-313. http://dx.doi.org/10.12973/tused.10283a

Jho, H. (2015). A literature review of studies on decision-making in socio-scientific issues. *Journal of the Korean Association for Science Education, 35*(5), 791–804. https://doi.org/10.14697/jkase.2015.35.5.0791

Juntunen, M. K., & Aksela, M. K. (2014). Education for sustainable development in chemistry – Challenges, possibilities and pedagogical models in Finland and elsewhere. *Chemistry Education Research and Practice, 15*(4), 488–500. https://doi.org/10.1039/c4rp00128a

Karışan, D., Tüzün, Ö. Y., & Zeidler, D. L. (2017). Quality of preservice teachers argumentation in socioscientific issues context. *International Journal of Human Sciences, 14*(4), 3504–3520. https:// doi.org/10.14687/jhs.v14i4.4949

Karpudewan, M., & Roth, W.-M. (2016). Changes in primary students' informal reasoning during an environment-related curriculum on socio-scientific issues. *International Journal of Science and Mathematics Education, 16*(3), 401–419. https://doi.org/10.1007/s10763-016-9787-x

Karsli Baydere, F., Ayas, A., & Çalik, M. (2020). Effects of a 5Es learning model on pre-service science teachers' conceptual understanding and science process skills: A case of gases and gas laws. *Journal of the Serbian Chemical Society, 85*(4), 559-573. https://doi.org/10.2298/JSC190329123D

Ke, L., Sadler, T.D., Zangori, L. & Friedrichsen, P.J. (2020). Students' perceptions of socio-scientific issue-based learning and their appropriation of epistemic tools for systems thinking, *International Journal of Science Education* https://doi.org/10.1080/09500693.2020.1759843

Koçak Altundağ, C. (2018). Context-based chemistry teaching within the 4Ex2 model: Its impacts on metacognition, multiple intelligence, and achievement. *Journal of Turkish Science Education, 15*(2), 1-12. http://dx.doi.org/10.12973/tused.10226a

Kolomuç, A., & Çalık, M. (2019). A comparison of academic staff's scientific habits of mind via socioscientific issues. *Yükseköğretim Dergisi, 9*(1), 67–74. https://doi.org/10.2399/yod.18.039

https://doi.org/10.33225/jbse/21.20.360

Levinson, R. (2006). Towards a theoretical framework for teaching controversial socio-scientific issues. *International Journal of Science Education, 28*(10), 1201–1224. https://doi.org/10.1080/09500690600560753

MacPhail, C., Khoza, N., Abler, L., & Ranganathan, M. (2015). Process guidelines for establishing Intercoder Reliability in qualitative studies. *Qualitative Research, 16*(2), 198–212. https://doi.org/10.1177/1468794115577012

Mandler, D., Mamlok-Naaman, R., Blonder, R., Yayon, M., & Hofstein, A. (2012). High-school chemistry teaching through environmentally oriented curricula. *Chemistry Education Research and Practice, 13*(2), 80-92. https://doi.org/10.1039/c1rp90071d

Marks, R., & Eilks, I. (2009). Promoting scientific literacy using a socio-critical and problem-oriented approach to chemistry teaching: Concept, examples, experiences. *International Journal of Environmental & Science Education, 4*(3), 231–245. https://www.ijese.net/makale/1396.

Memiş, E. K. (2014). Ilköğretim öğrencilerinin argümantasyon tabanli bilim öğrenme yaklaşimi uygulamalarina ilişkin görüşleri [Elementary students' ideas about on implementation of argumentation- based science learning approach]. *Kastamonu Education Journal, 22*(2), 401–418. https://dergipark.org.tr/en/download/article-file/209917

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded source book*. Thousand Oaks, Sage.

Molinatti, G., & Simonneau, L. (2015). A socio-environmental shale gas controversy: Scientists' public communications, social responsibility and collective versus individual positions. *Science Communication, 37*(2), 190–216. https:// doi.org/10.1177/1075547014560827

Mozeika, D., & Bilbokaite, R. (2010). Teaching and learning method for enhancing 15-16 years old students` knowledge as one of scientific literacy aspect in chemistry: Results based on research and approbation. *The International Journal of Educational Researchers, 3*(1), 1–16. http://ijer.penpublishing.net/makale/39.

National Research Council (NRC). (2000). *Inquiry and the National Science Education Standards*. National Academy Press.

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections*. London: The Nuffield Foundation.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, *25*(9), 1049–1079. https//doi.org/10.1080/0950069032000032199.

Parchmann, I., Gräsel, C., Baer, A., Nentwig, P., Demuth, R., & Ralle, B. (2006). "Chemie im Kontext": A symbiotic implementation of a context-based teaching and learning approach. *International Journal of Science Education, 28*(9), 1041–1062. https://doi.org/10.1080/09500690600702512

Pratiwi, Y. N., Rahayu, S., & Fajaroh, F. (2016). Socio-scientific issues (SSI) in reaction rates topic and its effect on the critical thinking skills of high school students. *Jurnal Pendidikan IPA Indonesia, 5*(2), 164–17. https://doi.org/10.15294/jpii.v5i2.7676

Price J. C., Walker I. A., & Boschetti, F. (2014). Measuring cultural values and beliefs about environment to identify their role in climate change responses. *Journal of Environmental Psychology, 37*, 8–20. https:// doi.org/ 10.1016/j.jenvp.2013.10.001

Rahem, A. (2018). Identifikasi kandungan alcohol dalam obat di apotik melalui pengamatan pada kemasan sekunder [Identification of alcohol content in medicines at the pharmacy through observation on secondary packaging]. *Journal of Halal Product and Research, 1*(2), 44–49. https://e-journal.unair.ac.id/JHPR/article/download/10510/5805

Regensburger, J., Lehner, K., Maisch, T., Vasold, R., Santarelli, F., Engel, E., Gollmer, A., Konig, B., Landthaler, M., & Baumler, W. (2010). Tattoo inks contain polycyclic aromatic hydrocarbons that additionally generate deleterious singlet oxygen. *Experimental Dermatology, 19*(8), 275–281. https://doi/org/10.1111/j.1600-0625.2010.01068.x

Roberts, D. A., & Bybee, R. W. (2014). Scientific literacy, science literacy, and science education. In N. G. Lederman and S. K. Abell (Eds.*), Handbook of research on science education* (2nd ed., pp. 545–558). New York: Routledge.

Romine, W. L., Sadler, T. D., & Kinslow, A. T. (2016). Assessment of scientific literacy: Development and validation of the quantitative assessment of socio-scientific reasoning (QuASSR). *Journal of Research Science Teaching, 54*(2), 1–22. https://doi.org/10.1002/tea.21368

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching*, *41*(5), 513-536. https://doi.org/10.1002/tea.20009

Sadler, T. D. (2009). Situated learning in science education: Socio-scientific issues as contexts for practice. *Studies in Science Education, 45*(1), 1–42. https://doi.org/10.1080/03057260802681839

Seery, M. (2015). *Putting chemistry in context*. https://eic.rsc.org/section/feature/putting-chemistry-in-context/2000106.article

Semilarski, H., Laius, A., & Rannikmäe, M. (2019). Development of Estonian upper secondary school students' biological conceptual understanding and competences. *Journal of Baltic Science Education, 18*(6), 955-970. https://doi.org/10.33225/jbse/19.18.955

Stuckey, M., & Eilks, I. (2014). Increasing student motivation and the perception of chemistry's relevance in the classroom by learning about tattooing from a chemical and societal view. *Chemistry Education Research and Practice, 15*(2), 156–167. https://doi.org/10.1039/c3rp00146f

Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013). The meaning of "relevance" in science education and its implications for the science curriculum. *Studies in Science Education, 49*(1), 1–34. https://doi.org/10.1080/03057267.2013.802463

Suri, H., & Clarke, D. (2009). Advancements in research synthesis methods: From a methodologically inclusive perspective. *Review of Educational Research, 79*(1), 395–430. https://doi.org/10.3102/0034654308326349

Tekin, N., Aslan, O., & Yilmaz, S. (2016). Research trends on socioscientific issues: A content analysis of publications in selected science education journals. *Journal of Education and Training Studies, 4*(9), 16–24. https://files.eric.ed.gov/fulltext/EJ1102850.pdf

Topçu, M. S., Muğaloğlu, E. Z., & Güven, D. (2014). Socioscientific issues in science education: The case of Turkey. *Educational Sciences: Theory & Practice, 14*(6), 14–22. https://doi.org/10.12738/estp.2014.6.2226

Tsai, J. C., Cheng, P. H., Liu, S. Y., & Chang, C. Y. (2019). Using board games to teach socioscientific issues on biological conservation and economic development in Taiwan. *Journal of Baltic Science Education, 18*(4), 634-645. https://doi.org/10.33225/jbse/19.18.634

Ültay, N., & Çalik, M. (2012). A thematic review of studies into the effectiveness of context-based chemistry curricula. *Journal of Science Education and Technology, 21*(6), 686–701. https://doi.org/10.1007/s10956-011-9357-5

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Ültay, N., Çalik, M. (2016). A comparison of different teaching designs of 'acids and bases' subject. *Eurasia Journal of Mathematics, Science and Technology Education, 12*(1), 57–86. https://doi.org/10.12973/eurasia.2016.1422a

Versprille, A., Zabih, A., Holme, T. A., McKenzie, L., Mahaffy, P., Martin, B., & Towns, M. (2017). Assessing student knowledge of chemistry and climate science concepts associated with climate change: Resources to inform teaching and learning. *Journal of Chemical Education, 94*(4), 407-417. http://dx.doi.org/10.1021/acs.jchemed.6b00759

Wan, Z. H., Wong, S. L., & Zhan, Y. (2013). Teaching nature of science to preservice science teachers: A phenomenographic study of Chinese teacher educators' conceptions. *Science & Education, 22*(10), 2593–2619. https://doi.org/ 10.1007/s11191-013-9595-4

Wiyarsi, A., & Çalik, M. (2019). Revisiting the scientific habits of mind scale for socio-scientific issues in the Indonesian context. *International Journal of Science Education, 41*(17), 2430–2447. https://doi.org/10.1080/09500693.2019.1683912

Wiyarsi, A., Pratomo, H. & Priyambodo, E. (2020). Vocational high school students' chemical literacy on context-based learning: A case of petroleum topic. *Journal of Turkish Science Education, 17*(1), 147-161. http://dx.doi.org/10.36681/tused.2020.18

Yapıcıoğlu, A. E., & Aycan, Ş. (2018). Pre-service science teachers' decisions and types of informal reasoning about the socio-scientific issue of nuclear power plants. *Educational Policy Analysis and Strategic Research, 13*(1), 31–53. https://doi.org/10.29329/epasr.2018.137.2

Zahara, H. S., & Atun, S. (2018). Effect of science-technology-society approach on senior high school students' scientific literacy and social skills. *Journal of Turkish Science Education*, *15*(2), 30-38. http://dx.doi.org/10.12973/tused.10228a

Zeidler, D. (2015). *Socioscientific issues*. In Encyclopedia of science education. Springer Netherlands.

Zeidler, D. L, & Nichols, B. H. (2009). Socioscientific issues: Theory and practice. *Journal of Elementary Science Education, 21*(2), 49–58.

Zowada, C., Frerichs, N., Zuin, V. G., & Eilks, I. (2020). Developing a lesson plan on conventional and green pesticides in chemistry education – a project of participatory action research. *Chemistry Education: Research and Practice, 21*(1), 141-153. https://doi.org/10.1039/C9RP00128J

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ENVIRONMENTAL AWARENESS, ATTITUDES, AND BEHAVIOUR OF PRESERVICE PRESCHOOL AND PRIMARY SCHOOL TEACHERS

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Abstract. *Environmental education represents an important factor in solving environmental issues and teachers have an important role in developing the environmental literacy of future generations. The aim of the present research was to assess and compare preservice preschool and primary school teachers' environmental awareness, attitudes, and behaviour, as well as their opinions about environmental education. The research was carried out with 152 Slovenian preservice teachers of the Faculty of Education, University of Primorska. The data were collected using a questionnaire. Results showed that students have a relatively high level of environmental awareness and mostly demonstrated a positive attitude towards nature and its protection. Students highlighted the importance of environmental education in early childhood. The research showed no significant differences in the responses of students of both programmes in general, which indicates that the course contents have a less significant influence on students' awareness, behaviour, and attitudes. According to the findings, there is a need for an improved course within the teacher training programme, especially with the implementation of more innovative teaching methods and activities to increase students' environmental literacy.*

Keywords: *environmental attitudes, environmental behaviour, environmental awareness, preschool education, primary school education, university students*

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Introduction

The modern lifestyle is marked by various environmental problems such as climate change, the greenhouse effect, water scarcity and water pollution, waste disposal, loss of biodiversity, overpopulation, ozone depletion, depletion of natural resources, environmental noise and light pollution, deforestation, acid rain etc. (Carta et al., 2018; IPSOS, 2019; IRP, 2019).

Global warming currently has an enormous impact on the entire planet. Human activities, primarily fossil fuel burning contribute to the increase of heat-trapping greenhouse gas levels in the Earth's atmosphere (NASA, 2021) which leads to an increase in the global average temperature. This significantly contributes to climate changes that are also characterised by rising sea levels, sea acidification, ice loss at the Earth's poles and in mountain glaciers, extreme weather events, vegetation cover changes, biodiversity loss and habitat degradation (National Academy of Sciences, 2020). The other important environmental issue is water-related problems. Since 2012, the water crisis has consistently ranked as the highest concern. Global water resources are under increasing pressure from population and economic growth, changes in production and trade patterns, rapidly growing demands, and climate change (Ercin, 2018; UNESCO, UN-Water, 2020;). Water scarcity and pollution limit the provision of quality water to meet human, environmental, social, and economic needs. Water pollution can be caused in a number of ways including substances from waste. Due to economic and population growth and urbanisation, the amount of waste is increasing rapidly. Waste accumulation and inappropriate waste management contribute to the change in environmental conditions and processes (Ferronato & Torretta, 2019; IRP, 2019), and have a negative impact on human and other life as well. One of the greatest threats is air pollution caused by solid or liquid particles and certain gases suspended in the air, such as sulphur dioxide, nitrogen dioxide, carbon monoxide, volatile organic compounds (VOCs), and particulate matter (PM). Primary pollutants are emitted directly into the air by industrial, domestic and traffic sources, while secondary pollutants (such as tropospheric ozone) forms when primary pollutants react in the atmosphere. Air pollution affects human health and contributes to global warming, acid rain, smog, ozone depletion etc. One of the more serious consequences of human activities is

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soil pollution. Soil acts as a "universal sink" and can accumulate or even concentrate contaminants which further affect the environment and human health (Ashraf et al., 2014). The major causes of soil pollution are agriculture, industry, waste disposal, mining, and atmospheric deposition (Cachada et al., 2018). Human activities (agriculture, land-use change, roads, mining, overgrazing, deforestation…) have also intensified soil erosion (Jenny et al., 2019) resulting in the loss of fertile land, increased pollution and sedimentation in streams and rivers, reduction of the productivity of ecosystems, and impacts on climate and biodiversity (IRP, 2019).

The last 50 years of scientific research have created greater awareness of the complex environmental problems and confirmed the need for urgent action (Burke et al., 2017; Valavanidis, 2019; WHO, 2020), such as international cooperation, interdisciplinary research, advanced technology and management tools, successful environmental policies, effective strategies for sustainable development, an increase in public awareness and the improvement of environmental education.

Research Focus

In response to the growing environmental crisis, developing environmentally literate citizens is crucial to understanding and overcoming environmental problems. Environmental literacy is a precursor for effective environmental protection (Kaya & Elster, 2019; Keinonen et al., 2016) and it could be achieved through environmental education. Effective education enhances environmental awareness, attitudes, values, and knowledge, as well as develops skills that prepare individuals to collaboratively undertake positive environmental action and responsible behaviour regarding the environment (Aminrad et al., 2013; Ardoin et al., 2020). It is important to raise the environmental literacy of children from an early age representing a critical period for developing thinking, behaving and emotional well-being (Türkoğlu, 2019). Several studies (Ardoin et al., 2020; Cohen & Horm-Wingerd, 1993; Meier & Sisk-Hilton, 2017) provide evidence of strongly positive outcomes in early childhood environmental education, such as an improvement in children's environmental awareness and knowledge, and positive attitudes towards the natural environment. In this context, teachers have a great responsibility and important role in providing adequate environmental literacy (Boca & Saraçlı, 2019; Türkoğlu, 2019), in a way that takes into account the child's developmental needs, interests, and abilities. According to Lwo et al. (2017), teachers influence a child's conception of the environment and play an important role in identifying and correcting misconceptions related to environmental problems (Yalcin & Yalcin, 2017). To achieve a positive impact on future generations, high-quality environmental education starting from preschool age is crucial.

Because of the important role of the teacher, many studies (Goulgouti et al., 2019; F. Sadik & S. Sadik, 2014; Tuncer et al., 2010) indicated a need to improve preservice teachers' environmental literacy. In this regard, understanding their perceptions about the environment could lead to more effective environmental education and greater levels of environmental literacy (Keinonen et al., 2016). Therefore, in this research the following components of environmental literacy of preservice teachers were assessed:

(1) *Environmental awareness* - fundamental knowledge of local and global environmental issues, and awareness of consequences (risk perceptions),
(2) *Environmental attitude* - attitude refers to values and feelings of environmental concern and motivation to active participation in environmental improvement and protection (UNESCO, 1978); value the interaction of human beings with the environment and their responsibility for environmental problems (Alvarez-Garcia et al., 2017),
(3) *Environmental behaviour* - individual behaviour that is respectful of the environment in everyday life, as well as participating in pro-environment actions (Alvarez-Garcia et al., 2017); this component is formed by consumption patterns, individual conservation, environmental activism, and leisure involving nature (Negev et al., 2008).

Research Aim and Research Questions

Many studies have examined the environmental literacy of preservice teachers, but there is a lack of research comparing the environmental literacy of preservice preschool and primary school teachers in the literature. Accordingly, the aim of the present research was to assess preservice preschool and primary school teachers' environmental awareness, attitudes and behaviour, and to find their opinions about environmental education in order to enrich the existing environmental education teacher training course.

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The research questions guiding this research were:

- What is the level of environmental awareness of preservice teachers?
- What are preservice teachers' attitudes and behaviours towards the environment?
- What are preservice teachers' opinions about environmental education?
- Is there any significant difference between preservice preschool and primary school teachers' environmental awareness, attitudes, and behaviours?

Research Methodology

General Background

In line with the aim of this research, a quantitative research was designed. The questionnaire was administered to the students of the Faculty of Education, University of Primorska (Republic of Slovenia), enrolled in the Preschool and Primary school teaching programme. The Preschool teaching programme is a first-degree programme, which lasts 3 years. The aim of the programme is to train preservice teachers for quality educational work with children in early childhood (between the ages of 1 and 6) and to work with their parents, colleagues, and other professionals. The Primary school teaching programme lasts 5 years: 4 years in the first-degree and 1 year in the second-degree programme. The major goal of the first-degree programme is to develop the preservice teachers' knowledge and pedagogical skills for teaching all subjects in primary school (students between the ages of 6 and 11). The research was carried out during the 2018/2019 and 2019/2020 academic years.

Sample

Convenience sampling was used in this research. This sampling approach was adopted due to its easy access for data collection. The sample consists of 152 undergraduate students who study at the University of Primorska, Faculty of Education. Of the 152, 90 (59.2 %) were Primary school teaching programme students and 62 (40.8 %) were Preschool teaching programme students, both groups of the second study year. Slovenia has three faculties of education, with an annual enrolment of 215 students in the Primary school teaching programme and 175 students in the Preschool teaching programme. The number of participants in this research represented approximately one-third of the average population of students enrolled in the second study year of both programmes.

The sample included students who have already attended the science course. Preservice primary school teachers learn about environmental issues mainly within mandatory science courses in the second year of study. The environmental education in the Preschool teaching programme is carried out mainly in the second year of study within the elective and the mandatory science course. The mandatory course of the Preschool teaching programme includes less environmental content in the curriculum (only some topics) in comparison with the Primary school teaching programme. For this reason, the participants were selected from the second year of study, after they took the environmental education within science courses.

The age of participants ranged between 20 and 22 years old. Most of the participants in both groups were females (preservice preschool teachers: 97.5 % females, 2.5 % males; preservice primary school teachers: 93.3 % females, 6.7 % males), which reflects the current state of the gender distribution of preschool and primary school teachers in Slovenia (preschool teachers: 97.3 % females, 2.7 % males; primary school teachers: 87.2 % females, 12.8 % males) (Statistical Office of the Republic of Slovenia, 2019). The socio-economic status of the students in both groups were similar. The participants were coming from different Slovenian regions.

Instrument and Procedures

The questionnaire was developed in order to gather the data. The questions and items were written in accordance with the aim of the research, some of them were adapted from relevant reviewed studies about university students' attitudes and behaviour towards the environment and environmental education (Alagoz & Akman, 2016; F. Sadik & S. Sadik, 2014; Slimak & Dietz, 2006). The questionnaire was divided into three parts: (a) the first part was used to assess students' environmental awareness, (b) the second part was used to explore students' environmental attitudes and behaviour, and (c) the third part was used to find out the students' opinions about environmental education.

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The first part included 3 open-ended questions and the scale consisted of 30 statements. Through the questions, the students' opinions on global and local environmental problems, and activities necessary to solve these problems were provided. A 5-point Likert-type scale with a list of 30 environmental issues was prepared. Students expressed their opinions about what environmental risk these issues pose. In the scale responses ranging from 1- *no risk* to 5- *very big risk*. The Cronbach's alpha value of the scale was .910. As stated by Nunnally (1978), the reliability of 70 or better can be accepted, so the results show that this part of the questionnaire is reliable.

In the second part of the questionnaire students' environmental attitudes and behaviour was explored using a 5-point Likert-type scale with 22 statements. The first set of 8 statements related to the attitudes towards nature (interaction of human beings with nature) and responsibility for environmental issues. With the second set of 14 statements about pro-environment actions in everyday life students' environmental behaviours were assessed. The responses ranged from 1- *strongly disagree* to 5- *strongly agree*. The mean values of the scales were presented for each statement. According to Veisi et al. (2018) mean values ranging from 1 to 2.49 are defined as a negative attitude, from 2.50 to 3.99 as a moderate attitude, and values from 4 to 5 as a positive attitude. The reliability of this scale is acceptable, as a Cronbach's alpha value (α = .716) higher than .70 was determined.

The third part of the questionnaire was focused on environmental education as teachers have a crucial role in promoting environmental literacy. Four questions were prepared to identify: students' opinions about the societal level of environmental literacy, what sources of information students assessed as the most reliable, what importance they attributed to environmental education at school, and whether they had acquired sufficient environmental knowledge at the faculty. For the first three questions, 4- and 5-point Likert-type scales were prepared. The last question was a close-ended question, with yes or no response.

The content validity of the questionnaire was examined and verified by an expert in science education who had more than 15 years of research and teaching professional experience. Based on suggestions for improvements of the questionnaire, some items were corrected. Then, the questionnaire was administrated to a pilot group (*N* = 32). After completing the questionnaire, the participants were asked to point out any ambiguities or difficulties they had experienced in completing the questionnaire. Considering their comments, the questionnaire has been adapted and the final form was designed.

Before administering the questionnaire, the participants were informed about the purpose of the research. Anonymity was guaranteed and any information that could reveal the identity of participants was avoided. The questionnaire was distributed to the students during the course. The students voluntarily participated in the research. Participants took approximately 15–20 minutes to complete the questionnaire.

Data Analysis

The quantitative data obtained from the questionnaire were analysed using SPSS statistical software (version 26.0). The answers for each statement of the 4- or 5-point Likert-type scale were rated with the corresponding number of points. To describe data for each statement of the Likert-type scale descriptive statistics were used: the measure of central tendency (*M*) and the measure of variability (*SD*). The reliability of each scale was determined using Cronbach's alpha coefficient. The qualitative data obtained from an open-ended question were firstly reviewed and then categorised in response categories. For each response category the measure of frequency (*f, f %*) was determined (how often the response was given). The normality of data was tested and in accordance with the results, the parametric *t*-test was used to determine the differences in environmental awareness, attitudes, and behaviour between the preservice primary school and preschool teachers. As stated by Sullivan and Feinn (2012), for better interpretation the substantive significance (effect size) and statistical significance (*p* value) are essential results to be reported. Therefore, an effect size analysis was conducted, and Cohen's *d* value was calculated. The value of .20 is referred to a small effect, .50 to a medium effect, and .80 to a large effect size (Cohen, 1992).

Research Results

Students' Environmental Awareness

As seen in Table 1, the students of both groups highlighted climate change (54.6 %), waste problem (42.8 %), air pollution (33.6 %), water pollution (32.2 %), and pollution in general (31.6 %) as the most important global environmental issues. The other global environmental issues mentioned by the students are deforestation, ozone

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layer depletion, biodiversity loss due to habitat destruction, traffic, excessive use of non-renewable resources, a lack of drinking water, ice melting, acid rain, soil pollution, intensive agriculture, population growth and urbanisation. Some students are convinced that oil spills, invasive species, GMOs, natural disasters, light and noise pollution are important environmental issues in the world. On a local scale, students thought that in Slovenia the most important environmental issues were the waste problem (27.0 %), pollution in general (26.3 %), climate change (19.1 %), air (13.8 %) and water pollution (9.9 %). No statistical difference between groups was found.

Table 1
Students' List of the Most Important Global and Local Environmental Issue (N = 152)

Environmental issue	Global scale		Local scale	
	f	*f%*	*f*	*f%*
Climate change	83	54.61	29	19.08
Waste problem	65	42.76	41	26.97
Air pollution	51	33.55	21	13.82
Water pollution	49	32.23	15	9.87
Pollution in general	48	31.58	40	26.32
Deforestation	32	21.05	1	.66
Ozone layer depletion	24	15.79	-	-
Biodiversity loss and habitat destruction	16	10.53	-	-
Traffic	15	9.87	4	2.63
Excessive use of non-renewable resources	14	9.21	4	2.63
Lack of drinking water	13	8.55	1	.66
Ice melting	12	7.89	-	-
Plastics	10	6.58	2	1.32
Acid rain	9	5.92	2	1.32
Soil pollution	6	3.95	-	-
Intensive agriculture	5	3.29	2	1.32
Population growth and urbanization	5	3.29	-	-

The students assessed the environmental risk of 30 selected environmental problems. The results are presented in Table 2, separately for students of the Preschool teaching programme and students of the Primary school teaching programme. The preservice preschool teachers rated the following human activities as the top five riskiest for the environment: activities leading to water scarcity and degradation of water quality, emissions of freons and halons which cause ozone layer depletion, hazardous waste, traffic, and plastic pollution. According to preservice primary school teachers, the human activities leading to water scarcity and degradation of water quality, global warming, plastic pollution, ozone layer depletion, and deforestation represent the most important environmental risks.

Preservice preschool teachers perceived the following environmental risks as the least threatening: overgrazing, sport fishing and hunting, spreading the invasive species, pollution with nanoparticles, and human population growth, while preservice primary school teachers chose overgrazing, sport fishing and hunting, damming rivers, nanoparticle pollution, and activities contributing to erosion and soil degradation.

There was no statistical difference in the opinions about environmental risks between preservice preschool and primary school teachers, except in their opinions about traffic (t = -2.945, p = .004), indoor air pollution (t = -2.479, p = .014), and damming rivers (t = -2.596, p = .011), where statistical differences were found. Although statistically

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significant differences in the mentioned three risks were found, it can be deduced from the Cohen's *d* value that the effect size is medium (traffic: $d = .506$) or small (indoor air pollution: $d = .398$; damming rivers: $d = .435$).

Table 2
Preservice Teachers' Perception of Environmental Risks Caused by Human Activity (1- no risk, 5- very big risk)

Environmental risk	Preschool *(N = 62)*		Primary School *(N = 90)*		*t*-test		Cohen's (*d*)
	M	*SD*	*M*	*SD*	*t*	*p*	
Water overuse and pollution	4.65	.630	4.58	.719	- .612	.542	.104
Emission of greenhouse gasses	4.37	.814	4.50	.691	1.020	.310	.172
Emission of freons and halons	4.52	.620	4.36	.798	-1.393	.166	.224
Plastic pollution	4.40	.839	4.40	.776	-0.024	.981	.000
Hazardous waste	4.45	.717	4.32	.668	-1.139	.256	.188
Deforestation	4.24	.824	4.33	.764	.702	.484	.113
Heavy metal pollution	4.27	.793	4.26	.829	-.139	.890	.012
Persistent organic pollutants	4.31	.801	4.17	.838	-1.029	.305	.171
Traffic	4.44	.716	4.04	.860	-2.945	.004	.506
Destruction of habitats	4.18	.758	4.18	.728	.003	.998	.000
Depletion of natural resources	4.06	.885	4.23	.835	1.195	.234	.198
Activities causing biodiversity loss	4.00	.768	4.13	.837	1.013	.313	.162
Inadequate disposal of medicinal waste	4.23	.913	3.94	.826	-1.941	.055	.333
Use of plant protection products	4.13	.914	3.97	.741	-1.160	.248	.192
Untreated waste water	3.81	.920	3.89	.929	.540	.590	.087
Emission of sulphur and nitrogen oxides	3.81	.743	3.79	.786	-.138	.890	.026
Overfishing	3.66	.940	3.80	.950	.888	.376	.148
Indoor air pollution	3.98	.967	3.57	1.092	-2.479	.014	.398
Human population growth	3.56	1.050	3.80	1.051	1.358	.177	.133
Activities causing eutrophication	3.68	.845	3.70	.785	.167	.868	.025
Wetland destruction	3.77	.931	3.61	.920	-1.069	.287	.173
Light and noise pollution	3.76	.953	3.62	1.023	-.838	.403	.142
Oil drilling	3.82	.859	3.53	.914	-1.964	.051	.327
GMOs	3.66	.809	3.52	1.073	-.910	.364	.147
Activities contributing to erosion	3.65	.770	3.47	.902	-1.308	.193	.215
Invasive species	3.31	1.018	3.63	1.022	1.942	.054	.314
Nanoparticles	3.52	.763	3.43	.887	-.615	.540	.109
Damming rivers	3.66	1.039	3.23	.937	-2.596	.011	.435
Sport fishing and hunting	3.00	.975	2.96	1.101	-.256	.798	.038
Overgrazing	2.76	1.066	2.80	.985	.249	.803	.039

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The third question of the questionnaire focused on the activities that students believed were important for solving environmental problems. According to the students from both groups (Table 3), the most important activities were proper waste treatment (40.8 %), environmental education (38.2 %), using public transport or riding a bike (24.3 %), and organising environmental protection activities (23.0 %). They also pointed out the need for adequate environmental policy and legislation (8.6 %), a reduction in the use of fossil fuels (8.6 %), reducing the amount of plastic (6.6 %), water-saving (6.6 %), lifestyle changes to preserve the environment (6.6 %), reducing the emissions of greenhouse gasses (5.9 %), and energy-saving (5.3 %). No statistical difference between groups was found.

Table 3
Preservice Teachers' Suggestions for Activities to Solve Environmental Problems (N = 152)

Activities	*f*	*f%*
Waste management (reduction, sorting, recycling, wastewater treatment)	62	40.79
Learning about environmental issues	58	38.16
Use of public transport or riding a bike	37	24.34
Organising activities for environmental protection	35	23.03
Adequate environmental policy and legislation	13	8.55
Use of renewable sources/reduction of fossil fuel	13	8.55
Less packaging, less plastic	10	6.58
Water-saving	10	6.58
Lifestyle changes to preserve the environment	10	6.58
Reduction of greenhouse gas emissions	9	5.92
Energy-saving	8	5.26

Students' Environmental Attitudes and Behaviour

As seen in Table 4, students showed a positive environmental attitude (mean values from 4 to 5), except for the last statements about the role of science and technology in solving environmental problems. There were no significant differences in the attitudes towards nature and environmental responsibility between students of both programmes. Mean values indicated that with most of the statements the preservice preschool teachers expressed greater agreement than the preservice primary school teacher (Table 4).

With the second set of statements about pro-environment actions in everyday life students' environmental behaviours were assessed. A higher mean value represented more sensitivity to the environment. Results indicated that students expressed the highest agreement with the statements about supporting the use of renewable energy sources, reducing waste volume and recycling waste (Table 4). Students from both groups expressed the lowest agreement with the statement about reading articles related to environmental issues and active participation in environmental protection activities. There were no significant differences between groups, except with the statement "*I have paid attention to my consumption habits in order to contribute to environmental protection.*" (t = -2.878, p = .005), but the effect size was slightly under the limit value which determines the medium effect size (d = .475).

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Table 4
Preservice Teachers' Environmental Attitudes and Behaviours (1- strongly disagree; 5- strongly agree)

Environmental attitudes and behaviours	Preschool (*N* = 62)		Primary School (*N* = 90)		*t*-test		Cohen's (*d*)
	M	*SD*	*M*	*SD*	*t*	*p*	
I like being in nature because I relax.	4.73	.577	4.67	.540	-.637	.525	.107
Protecting nature is important to me.	4.61	.583	4.46	.737	-1.467	.145	.226
Nature must be preserved primarily due to plants, animals, bacteria, viruses and fungi, and not just for the well-being of people.	4.53	.783	4.48	.796	-.417	.677	.063
I believe that environmental problems will only intensify.	4.42	.615	4.32	.776	-.858	.392	.143
Industry should be required to use recycled material, although it may cost more than production from new raw materials.	4.27	.793	4.37	.771	.718	.474	.128
As an individual, I can greatly contribute to the preservation of the environment.	4.16	.872	4.11	.917	-.338	.736	.056
I think people in developed societies should adopt a more conservative way of life to solve environmental problems.	4.03	.905	3.92	.824	-.764	.446	.127
The development of science and technology will eliminate environmental problems.	2.16	.853	2.31	.816	1.092	.277	.180
I support the use of renewable energy sources.	4.71	.584	4.68	.650	-.316	.753	.049
Before I discard packaging, I reduce its volume.	4.60	.735	4.54	.823	-.411	.682	.077
I regularly recycle waste.	4.39	.797	4.19	.982	-1.370	.173	.224
When I go to the store, I take a shopping bag with me.	4.26	1.007	4.21	.954	-.292	.771	.051
I switch off electrical appliances if I am not using them.	4.05	1.078	3.88	1.216	-.910	.365	.148
In the winter I'm careful not to heat my home more than necessary.	3.82	.933	3.98	1.101	.936	.351	.157
I have paid attention to my consumption habits to contribute to environmental protection.	3.74	.808	3.34	.876	-2.878	.005	.475
I give preference to biodegradable products from non-degradable.	3.65	1.057	3.37	.977	-1.646	.102	.275
I give preference to recyclable products from non-recyclable.	3.65	1.026	3.32	.958	-1.959	.052	.332
If possible, I choose a bike ride or public transport instead of driving a car.	3.53	1.036	3.30	1.434	-1.159	.248	.184
I always warn people if they are doing damage to the environment.	3.39	.981	3.46	.926	.437	.663	.073
I'm willing to pay more for environmentally friendly products.	3.39	1.014	3.24	.998	-.861	.391	.149
I actively participate in environmental protection activities.	3.13	1.109	2.98	1.060	-.842	.402	.138
I read articles related to environmental issues.	2.50	.919	2.43	1.006	-.423	.673	.073

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Students' Opinions about Environmental Education

The third part of the questionnaire was dedicated to the collection of students' opinions about environmental education. The first question aimed to find out what sources of information about environmental issues students assessed as the most reliable. The students expressed their opinion about each selected source with responses ranging from 1- *the least reliable* to 5- *the most reliable.* In Table 5 the mean value and standard deviations for each source are presented. Results showed that preservice primary school teachers thought that the education system was the most reliable source of information (M = 4.46), while family (M = 3.09) and friends (M = 2.72) were the least reliable sources. The preservice preschool teachers considered books to be the most reliable information source (M = 4.35) and friends as the least reliable source (M = 2.90). According to the results of the t-test, it was determined that there was a statistically significant difference between the two study programmes with regard to students' opinions about the education system as the most reliable sources (t = 1.993, p = .049). The Cohen's d value indicated a small effect size (d = .344).

Table 5
Preservice Teachers' Opinions on the Reliability of Information Sources about Environmental Issues (1- the least reliable, 5- the most reliable)

Information sources	Preschool (N = 62)		Primary School (N = 90)		t-test		Cohen's (d)
	M	SD	M	SD	t	p	
Education system	4.21	.832	4.46	.603	1.993	.049	.344
Books	4.35	.851	4.26	.815	-.719	.473	.108
State institution	3.92	.874	3.90	1.006	-.123	.902	.021
Local institution	3.90	.783	3.76	.952	-1.045	.298	.161
Voluntary organisations	3.82	.915	3.81	1.253	-.062	.951	.009
Radio, TV	3.40	.914	3.40	.922	-.021	.983	.000
Magazines, journals	3.31	.951	3.37	.893	.398	.691	.065
Internet	3.21	.994	3.11	.988	-.602	.548	.101
Family	3.21	.926	3.09	1.013	-.748	.456	.124
Friends	2.90	.953	2.72	.972	-1.137	.257	.187

In the next question, students were asked to express their opinions on the environmental literacy of various generations (primary school students, faculty students, their parents, their grandparents). As seen in Table 6, students estimated themselves as having the highest level of environmental literacy, while their grandparents had the lowest. There was no statistical difference in students' opinions between groups and Cohen's d values showed a small effect size.

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Table 6
Preservice Teachers' Opinions on Environmental Literacy (EL) in our society (1- low, 4- very high)

EL of different generations	Preschool (N = 62)		Primary School (N = 90)		t-test		Cohen's (d)
	M	SD	M	SD	t	p	
EL student's self-assessment	3.02	.496	3.06	.568	-.736	.463	.075
EL of faculty students	3.00	.512	2.94	.548	.761	.448	.113
EL of parents	2.85	.596	2.89	.771	-.307	.760	.058
EL of primary school students	2.74	.676	2.60	.667	1.282	.202	.208
EL of grandparents	2.66	.767	2.44	.937	1.563	.120	.257

The next question on the questionnaire was focused on environmental education in school. Students' opinions on three statements regarding the importance of environmental education are presented in Table 7. Students of both groups expressed the highest agreement with the statement about the importance of environmental education in the preschool period. There was no statistical difference between groups and Cohen's *d* values showed a small effect size ($d = .219$). They also expressed a high level of agreement with the other two statements about the positive effect of environmental education on a respectful attitude to nature and knowledge about environmental issues, but there was no difference between groups.

Table 7
Preservice Teachers' Opinions on Environmental Education (1- strongly disagree, 5- strongly agree)

Statement about environmental education	Preschool (N = 62)		Primary School (N = 90)		t-test		Cohen's (d)
	M	SD	M	SD	t	p	
Environmental education is important already in the pre-school period and then during schooling it has to be upgraded.	4.60	.778	4.74	.464	1.340	.184	.219
Environmental education contributes to becoming more respectful of nature.	4.35	.726	4.34	.737	-.086	.932	.014
Environmental education in school influences the later understanding of environmental issues.	4.26	.767	4.31	.744	.427	.670	.066

The last question aimed to find out whether the students had acquired sufficient environmental knowledge. The majority of students from the primary school education programme (43.3 %) thought that they acquired enough knowledge, while the majority of the students from the preschool education programme (40.3 %) thought the opposite. Many students were unable to assess whether they had acquired sufficient environmental knowledge at school or not.

Discussion

For the participants in this research the most important environmental issues in the world were climate change, waste problems, air and water pollution (Table 1). That is in accordance with the results of the Ipsos global survey about the top global environmental issues in 2019 (Ipsos, 2019), which are the biggest challenges of the twenty-first century posing risks to the environment and human health. Air pollution and climate change were also identified as the world's biggest environmental problems by preservice teachers in the research done by Alagoz and Akman

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(2016). As reported by Kukkonen et al. (2012), university students perceived climate change and a lack of clean water as the most serious environmental problems. The present research revealed that the majority of participants also indicated the waste problem as the major local environmental problem in the Republic of Slovenia (Table 1). This students' opinion was expected because recently special attention has been dedicated to the two national biggest hazardous waste management companies and to the waste management system which is predominantly decentralised and organised at the municipal level. This issue was also widely reported in newspapers and other mass media. Similar global and local environmental problems as mentioned above have been highlighted in several studies (Keinonen et al., 2016; Kukkonen et al., 2012; F. Sadik & S. Sadik, 2014), but listed in a different order of importance due to the characteristics of the specific country and education system where the research took place. The results also depend on the time (year) when the survey was conducted as the environmental topics change daily (Aydin, 2010) and of the mass media influence on environmental issue perceptions of all society, especially young people and children (Keinonen et al., 2016; Matyjas, 2015). The perception of environmental issues contributes to a better understanding and higher awareness of environmental hazards and the negative consequences of anthropogenic activities. Therefore, in this research students' risk perception (awareness of consequences) on 30 environmental problems were analysed. According to the students, the highest environmental risk was the overuse of water resources and water pollution. The results may reflect the fact that water pollution and the problem of water scarcity are important learning topics in many curricula of Slovenian primary and secondary schools leading to the high awareness of water issues. Moreover, they indicated global warming, emissions of freons and halons, hazardous waste, traffic, plastic pollution, and deforestation as very important environmental risks. Some risks such as overgrazing, sport fishing and hunting, nanoparticle pollutions were estimated as less important risks, likely due to a low level of knowledge about these risks. Therefore, environmental education must provide knowledge and awareness about current and especially lesser-known environmental issues. Despite the different curriculum no significant difference in the level of environmental risk perception (Table 2) between students of the Preschool teaching programme and students of the Primary school teaching programme was detected. However, some statistical difference between groups was observed in their opinions about traffic, indoor air pollution, and damming rivers. Durmuş-Özdemir and Şener (2016) found a significant positive relationship between the students' environmental education and their environmental risk perceptions. The importance of education in understanding various environmental risks and raising awareness on the environmental issue was also confirmed by several studies (Alagoz & Akman, 2016; Carmi & Alkaher, 2019; Ergin, 2019). Students need to be aware of environmental problems in order to understand and solve them (Metin et al., 2011). In accordance with the prevailing opinion of students on the most important global and local environmental issues, the majority stressed the importance of proper waste management as the most effective activity for the solution of environmental issues (Table 3). They also indicated the environmental education as an important way to overcome environmental problems, also confirmed by several previous studies (Alagoz & Akman, 2016; Türkoğlu, 2019). Environmental education significantly affects the prevention, control, and elimination of environmental risks (Hesami Arani et al., 2016). In the present research, many students viewed public transport as an activity which could mitigate environmental issues. This result has been expected since Slovenia has an extremely high share of private cars in passenger transport, which is the most unsustainable mode of transport (Kušar et al., 2014). In addition, students suggested other solutions to environmental problems such as environmental protection activities, adequate environmental policy and legislation, use of renewable sources, and reduction in fossil fuel usage, greenhouse gas emission, and plastic, conservation of water and electricity, and lifestyle changes.

In order to study the students' environmental attitudes and behaviours (the second part of the questionnaire), they were asked to indicate their views on selected statements using five-point Likert scales (Table 4). The statements which received the strongest agreement (in both groups) regarding environmental attitudes were "*I like being in nature because I relax.*" and "*Protecting nature is important to me.*", that is in accordance with the findings of Koc and Kuvac (2016). On the other hand, students from both groups expressed the lowest agreement with the statement about the development/progress of science and technology as the remedy to environmental problems (Table 4). A possible reason for this can be their own experience and online information regarding the negative impact of technology (such as non-ionising radiation, information security threats, technostress, etc.). Rapid progress in the science and technology has significantly improved the quality of our lives (improvement in healthcare, communication, energy supply …), although there is also some negative impact on our lives and surroundings. For example, technology contributes many solutions to environmental issues, but it also represents part of that problem (Proudfoot & Kelley, 2017). The contrasting roles of science and technology in environmental challenges

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have been widely discussed by Voulvoulis and Burgman (2019), who highlighted the importance of integrated, interdisciplinary and holistic solutions, and a better definition of environmental problems.

Students from both groups expressed the strongest support for the use of renewable energy sources because non-renewable energy releases greenhouse gasses and other pollutants into the atmosphere causing global warming and climate change which was perceived by the students as the most important global environmental issue (Table 1). Similarly, as in the case of students' estimation of the impact of human activity on the environment, there were no significant differences between the results of students from both groups, with the exception of the statement "*I have paid attention to my consumption habits to contribute to environmental protection.*" (t = -2.878, p = .005).

The research revealed that for the preservice primary school teachers, the most reliable sources of information about environmental issues were the education system, and books for preservice preschool teachers (Table 5). The statistically significant difference between groups is likely due to the different courses of Primary and Preschool teaching programmes. Keinonen et al. (2014) also found that students perceived school/education as the most reliable source of information concerning environmental issues. The present research also shows that local and state institutions and voluntary organisations are important factors that awaken environmental awareness for the majority of students. The latter indicates the important influence of the growing role of non-state actors on students' opinions on environmental status. For the participants of this research, the internet and TV were moderately reliable information sources, however, other studies (Kukkonen et al., 2012; F. Sadik & S. Sadik, 2014; Yurttaş & Sülün, 2010) have shown that internet and TV were considered the most important factors that awaken environmental awareness. Besides the important influence of school, institutions and media, children also acquire information about environmental issues from friends and family. Nevertheless, the development of behaviour and skills, awareness and sensitivity towards the environment begins with the attitude of parents (Halmatov & Ata, 2017), the participants assessed family and friends as the least reliable sources of information, likely due to the greater influence of other sources in the period of the early adulthood. This is in accordance with the research done by Keinonen et al. (2014).

As environmental literacy is assumed to be an important prerequisite for environmental protection and conservation, the students' views on the levels of environmental literacy in our society were collected. According to the findings, students rated themselves as the most environmentally literate individuals, while they assessed their grandparents at the lowest level (Table 6). This is mostly due to the different lifestyles and living conditions of previous generations. The economic conditions, education and information level, social status, location of residency, political ideology and the government's environmental regulation information, and environmental pollution as well, significantly contribute to public attention to the environment (Üstün & Celep, 2007).

The results of this research revealed that the majority of students were aware of the importance of environmental education in the preschool period (Table 7), but preservice primary school teachers indicated a higher level of importance than preservice preschool teachers. According to Buldur and Ömeroğlu (2018), childhood is a period of very intense development during which attitudes and awareness are formed and developed. The preschool period is crucial because in this period the attitudes of individuals towards the environment are created (Wilson, 1996). Students of both programmes strongly agreed that environmental education contributes to becoming more respectful of nature and also influences a later understanding of environmental issues and attitudes towards the environment in the later period.

Preservice primary school teachers thought that they had received sufficient environmental knowledge during schooling, while preservice preschool teachers believed that they were not informed enough about the environmental topic. The reason for this is most likely in the previously described difference in courses of both programmes.

This research has some limitations. First, the sample size was small *(N* = 152), because this research was carried out only in one university with an annual enrolment of 60 students at preschool teaching programme and 60 students at primary school teaching programme. Therefore, the results cannot be generalized. For future research, more students should be involved in the sample, not only from Slovenia but also from other countries. Second, this research compared only environmental awareness, attitudes, and behaviours of preservice teachers, but the environmental knowledge as an important component of environmental literacy was not assessed. In future work, it will be meaningful to examine the environmental knowledge of the preservice teachers. Finally, the participants may have completed the questionnaire superficially and did not devote sufficient time to a thorough reading and reflection on each statement or question.

Nevertheless, the findings should contribute to future research about the environmental literacy of preservice teachers. Additional research on environmental awareness, attitudes, and behaviours of preservice preschool and

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primary school teachers including a comparison with the other countries, could help to design an effective course of environmental education for preservice teachers who are important predictors of environmental literacy of future generations. It is important to highlight the significance of monitoring the effectiveness and efficiency of environmental courses and realising continuous evaluation of them.

Conclusions and Implications

The present research gives insight into the preschool and primary school preservice teachers' environmental awareness, attitudes, and behaviours. Findings from the first part of the questionnaire showed that the students are mostly aware of the major global and local environmental problems. The highest perceived environmental risks were the overuse of water resources and water pollution. As the most effective activities to solve the environmental problems students highlighted waste management and environmental education, while energy-saving was on their opinion the least important.

Results indicate that students from both groups showed a positive attitude to the natural environment and a great concern for environmental protection. On the other hand, the majority of students specified the lowest level of agreement with the statement about the development/progress of science and technology as the remedy for environmental problems. So, there is a need to improve communication and explanation about the role of science and technology in our lives.

Analysis of results regarding environmental behaviour indicated that students from both groups expressed the strongest support for the use of renewable energy sources. The research revealed that the most reliable sources of information about environmental issues are the education system and books. In the case of the education system, a statistically significant difference between the groups was detected. Students found the internet and TV to be a moderately reliable source, while family and friends were the least reliable. The majority of students considered themselves more environmentally literate than their parents and grandparents. Students are aware of the importance of environmental education from an early age and its contribution to environmental awareness, behaviour, and attitudes of the citizens.

There were no important differences in the responses of students from both programs in general, which indicates that the course contents have a less significant influence on students' awareness, behaviour, and attitudes. This is probably because the course is based mostly on theoretical knowledge about environmental issues. In order to educate more environmentally qualified and conscious teachers, it is important to enrich and improve the environmental education teacher training course to provide teachers with the necessary knowledge, competencies, skills, tools, models, and examples of good teaching practices. It is essential to implement more innovative teaching methods and activities to increase students' interest, knowledge, and sensitivity towards environmental problems, such as (1) inquiry-based learning with hands-on activities to develop critical and creative thinking skills, (2) outdoor learning to foster sensitivity and respect for nature, (3) experiential learning, (4) project work focusing on local topics, (5) discussions about the current environmental problems, with an emphasis on expressing their opinions, personal ideas, and suggestions for solving these problems, (6) cross-curricular evaluation of environmental problems, (7) activities to engage students in environmentally responsible behaviour and healthy lifestyles, (8) involvement of scientists, experts, and local institutions in environmental learning. Besides that, the society needs to be aware that environmental problems are not country-specific, as many environmental problems extend across national borders. Currently, the Earth is facing several environmental issues that require the efforts of all countries of the world. International actions and agreements have already been very effective in reducing acid depositions and protecting the ozone layer. Similarly, some networks, such as Global Environmental Education Partnership (GEEP, 2021) and Foundation for Environmental Education (FEE, 2021), have been already designed to strengthen environmental education on a global scale. However, there is a necessity for more targeted international cooperation to achieve environmental education objectives. In this regard, a network of faculties of education and other educational institutions needs to be set up to support the preservice teacher's professional development by promoting their environmental literacy and training them for better environmental teaching.

The analysis of preservice teachers' environmental literacy represents an important basis for the improvement of the environmental education courses at the faculties of education. So, this research should be upgraded by cross-country analysis of the preservice teachers' environmental literacy, whereas there are variations in the educational system and environmental policies among countries.

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References

Alagoz, B., & Akman, O. (2016). A study towards views of teacher candidates about national and global environmental problems. *International Journal of Research in Education and Science*, *2*(2), 483–493. https://www.ijres.net/index.php/ijres/article/view/125

Alvarez-Garcia, O., Sureda-Negre, J., & Comas-Forgas, R. (2017). Assessing environmental competencies of primary education pre-service teachers in Spain. A comparative study between two universities. *International Journal of Sustainability in Higher Education, 19*(1), 15–31. https://doi.org/10.1108/IJSHE-12-2016-0227

Aminrad, Z., Sayed Zakariya, S. Z. B., Samad Hadi, A., & Sakari, M. (2013). Relationship between awareness, knowledge, and attitudes towards environmental education among secondary school students in Malaysia. *Applied Sciences Journal, 22*(9), 1326–1333. https://www.semanticscholar.org/paper/Relationship-Between-Awareness%2C-Knowledge-and-Among-Binti-Zakariya/addab62e12c205b7a65eee4611577cc4bbfea7dc

Ardoin, N. M., Bowers A. W., & Gaillard E. (2020). Environmental education outcomes for conservation: A systematic review. *Biological Conservation*, *241*, 108224. https://doi.org/10.1016/j.biocon.2019.108224

Ashraf, M. A., Maah, M. J., & Yusoff, I. (2014). Soil contamination, risk assessment and remediation. In M. C. Hernandez-Soriano (Ed.), *Environmental risk assessment of soil contamination* (pp. 3–56). IntechOpen. http://dx.doi.org/10.5772/57287

Aydin, F. (2010). Geography teacher candidates' views about environment problems and environment education (Gazi University Case). *International Online Journal of Educational Sciences, 2*(3), 818–839. https://iojes.net/?mod=makale_tr_ozet&makale_id=41343

Başal, H. A., Özen, R., & Kahraman, P. B. (2015). Preschool teacher candidates' sensitivities and attitudes towards environment. *International Online Journal of Educational Sciences, 7*(3), 27–37.

Boca, G. D., & Saraçlı, S. (2019). Environmental education and student's perception, for sustainability. *Sustainability*, *11*(6), 1553. https://doi.org/10.3390/su11061553

Buldur, A., & Ömeroğlu, E. (2018). An examination of the relationship between pre-school children's and their teachers' attitudes and awareness towards the environment. *Journal of Education and Learning, 7*(2), 221–229. http://www.ccsenet.org/journal/index.php/jel/article/view/72418

Burke, T. A., Cascio, W. E., Costa, D. L., Deener, K., Fontaine, T. D., Fulk, F. A., Jackson, L. E., Munns, W. R., Orme-Zavaleta, J., Slimak, M. W., & Zartarian, V. G. (2017). Rethinking environmental protection: Meeting the challenges of a changing world. *Environmental Health Perspectives*, *125*(3), A43–A49. https://doi.org/10.1289/EHP1465

Cachada, A., Rocha-Santos, T., & Duarte, A. C. (2018). Soil and pollution: An introduction to the main issues. In A. Cachada, T. Rocha-Santos, & A. C. Duarte (Eds.), *Soil pollution* (pp. 1–28). Elsevier Academic Press. https://doi.org/10.1016/B978-0-12-849873-6.00001-7

Carmi, N., & Alkaher, I. (2019). Risk literacy and environmental education: Does exposure to academic environmental education make a difference in how students perceive ecological risks and evaluate their risk severity? *Sustainability*, *11*(22), 6350. https://doi.org/10.3390/su11226350

Carta, M. G., Preti, A., & Akiskal, H. S. (2018). Coping with the new era: Noise and light pollution, hyperactivity and steroid hormones. towards an evolutionary view of bipolar disorders. *Clinical Practice & Epidemiology in Mental Health*, *14,* 33–36. http://dx.doi.org/10.2174/1745017901814010033

Cohen, S., & Horm-Wingerd, D. (1993). Children and the environment: Ecological awareness among preschool children. *Environment and Behavior, 25*, 103–120. https://doi.org/10.1177/0013916593251005

Cohen, J. (1992). A power primer. *Psychological Bulletin*, *112*(1), 155–159. https://doi.org/10.1037/0033-2909.112.1.155

Durmuş-Özdemir, E., & Şener, S. (2016). The impact of higher education on environmental risk perceptions. *China-USA Business Review*, *15*(9), 459–471. https://doi.org/10.17265/1537-1514/2016.09.005

Ercin, E. (2018). Overuse of water resources: Water stress and the implications for food and agriculture. In P. Ferranti, E. M. Berry, & J. R. Anderson (Eds.), *Encyclopaedia of Food Security and Sustainability* (pp. 206–211). Elsevier. https://doi.org/10.1016/B978-0-08-100596-5.21998-7

Ergin, D. Y. (2019). Environmental awareness of teacher candidates. *World Journal of Education, 9*(1), 152–161. https://doi.org/10.5430/wje.v9n1p152

FEE (2021, March 10). Foundation of environmental education. Positive change on a global scale. https://www.fee.global/

Ferronato, N., & Torretta, V. (2019). Waste mismanagement in developing countries: A review of global issues. *International Journal of Environmental Research and Public Health, 16*(6), 1060. https://doi.org/10.3390/ijerph16061060

GEEP (2021, March 10). Global environmental education partnership. A champion for environmental education around the world. https://thegeep.org/

Goulgouti, A., Plakitsi, A., & Stylos, G. (2019). Environmental literacy: Evaluating knowledge, affect, and behavior of pre-service teachers in Greece. *Interdisciplinary Journal of Environmental and Science Education, 15*(1), e02202. https://doi.org/10.29333/ijese/6287

Halmatov, M., & Ata, S. (2017). An assessment of the contribution of parents to environmental awareness for children in the preschool age of 5–6 years. *International Journal of Education, Science and Technology, 3*(2), 78–87. https://www.researchgate.net/publication/319903432

Hesami Arani, M., Bagheri, S., & Ghaneian, M. T. (2016). The role of environmental education in increasing the awareness of primary school students and reducing environmental risks. *Journal of Environmental Health and Sustainable Development, 1*(1), 9–17. http://jehsd.ssu.ac.ir/article-1-22-fa.pdf

IPSOS Report. (2019). *Earth Day 2019. How does the world perceive our changing environment?* IPSOS Global Advisor. https://www.ipsos.com/sites/default/files/ct/news/documents/2019-04/earth-day-2019-report-2019-04-19-v1.pdf

IRP. (2019). *Global resources outlook 2019: Natural resources for the future we want.* United Nations environment programme. https://www.resourcepanel.org/reports/global-resources-outlook

https://doi.org/10.33225/jbse/21.20.373

Jenny, J. P., Koirala, S., Gregory-Eaves, I., Francus, P., Niemann, C., Ahrens, B., Brovkin, V., Baud, A., Ojala, A. E. K., Normandeau, A., Zolitschka, B., & Carvalhais, N. (2019). Human and climate global-scale imprint on sediment transfer during the Holocene. *Proceedings of the National Academy of Sciences*, *116*(46), 22972–22976. https://doi.org/10.1073/pnas.1908179116

Kaya, V. H., & Elster, D. (2019). A critical consideration of environmental literacy: Concepts, contexts, and competencies. *Sustainability, 11*, 1581. https://doi.org/10.3390/su11061581

Keinonen, T., Yli-Panula, E., Svens, M., Vilkonis, R., Persson, C., & Palmberg, I. (2014). Environmental issues in the media - students´ perceptions in the three Nordic-Baltic countries. *Journal of Teacher Education for Sustainability, 16*(1), 32–53. https://doi.org/10.2478/jtes-2014-0002

Keinonen, T., Palmberg, I., Kukkonen, J., Yli-Panula, E., Persson, C., & Vilkonis, R. (2016). Higher education students' perceptions of environmental issues and media coverage. *Discourse and Communication for Sustainable Education, 7*(1), 5–22. https://doi.org/10.1515/dcse-2016-0001

Koc, I., & Kuvac, M. (2016). Preservice science teachers' attitudes toward environment. *International Journal of Environmental and Science Education, 11*(13), 5925–5941. http://www.ijese.net/makale/753.html

Kukkonen, J., Kärkkäinen, S., & Keinonen, T. (2012). University students' information sources of education for sustainable development issues and their perceptions of environmental problems. *Problems of education in the 21st century, 39,* 93–104. http://www.scientiasocialis.lt/pec/files/pdf/vol39/93-104.Kukkonen_Vol.39.pdf

Kušar, U., Bernard Vukadin, B., & Kovač, N. (Eds.) (2014). *Environmental indicators in Slovenia*. Ministry of Agriculture and the Environment - Slovenian Environmental Agency.

Lwo, L.-S., Fu, J.-H., & Chang, C.-C. (2017). The ecological worldviews and local environmental concerns among secondary school teachers. *Journal of Baltic Science Education, 16* (5), 706–722. http://www.scientiasocialis.lt/jbse/files/pdf/vol16/706-722.Lwo_JBSE_Vol.16_No.5.pdf

Matyjas, B. (2015). Mass media and children. Globality in everyday life. *Social and Behavioral Sciences, 174*, 2898–2904. https://doi.org/10.1016/j.sbspro.2015.01.1026

Meier, D., & Sisk-Hilton, S. (2017). Nature and environmental education in early childhood. *The New Educator*, *13*(3), 191–194. https://doi.org/10.1080/1547688X.2017.1354646

Metin, M., Coskun, K., & Topkaya, Y. (2011). Are the primary teachers aware of environmental problems? *World Applied Sciences Journal*, *13*(3), 396–403. http://www.idosi.org/wasj/wasj13(3)/2.pdf

NASA (2021, January 19). *Overview: Weather, global warming and climate change, global climate change*. https://climate.nasa.gov/resources/global-warming-vs-climate-change/

National Academy of Sciences. (2020). *Climate change: Evidence and causes: Update 2020*. The National Academies Press. https://doi.org/10.17226/25733.

Negev, M., Sagy, G., Garb, Y., Salzberg, A., & Tal, A. (2008). Evaluating the environmental literacy of Israeli elementary and high school students. *The Journal of Environmental Education*, *39*(2), 3–20. https://doi.org/10.3200/JOEE.39.2.3-20

Nunnally, J. C. (1978). *Psychometric theory* (2nd ed.). New York: McGraw-Hill.

Proudfoot, R., & Kelley, S. (2017). *Can technology save the planet?* WWF Australia. https://www.wwf.org.au/ArticleDocuments/360/pub-can-technology-save-the-planet-30may17.pdf.aspx?Embed=Y

Sadik, F., & Sadik, S. (2014). A study on environmental knowledge and attitudes of teacher candidates. *Procedia-Social and Behavioral Sciences*, *116*, 2379–2385. https://doi.org/10.1016/j.sbspro.2014.01.577

Slimak, M. W., & Dietz, T. (2006). Personal values, beliefs, and ecological risk perception. *Risk Analysis, 26*(6), 1689–1705. https://doi.org/10.1111/j.1539-6924.2006.00832.x

Sullivan, G. M., & Feinn, R. (2012). Using effect size - or why the *p* value is not enough. *Journal of Graduate Medical Education*, *4*(3), 279–282. https://doi.org/10.4300/JGME-D-12-00156.1

Tuncer, G., Sungur, S., Tekkaya, C., & Ertepinar, H. (2010). A comparative study on pre-service teachers' and elementary students' attitudes towards environment. *International Research in Geographical Environmental Education, 16*(2), 188–198. https://doi.org/10.2167/irgee217.0

Türkoğlu, B. (2019). Opinions of preschool teachers and pre-service teachers on environmental education and environmental awareness for sustainable development in the preschool period. *Sustainability, 11*, 4925. https://doi.org/10.3390/su11184925

UNESCO. (1978). *Final report, intergovernmental conference on environmental education*. UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000032763

UNESCO, UN-Water. (2020). *United Nations world water development report 2020*: *Water and climate change*. UNESCO. https://www.unwater.org/publications/world-water-development-report-2020/

Üstün, B., & Celep, B. (2007). The connection between environmental awareness and socio-economic and cultural structure. *WIT Transactions on Ecology and the Environment*, *102*. https://doi.org/10.2495/SDP070602

Valavanidis, A. (2019). Current environmental issues and emerging global challenges in the 21st century for environmental protection and sustainable development. https://www.researchgate.net/publication/337918765

Veisi, H., Lacy, M., Mafakheri, S., & Razaghi, F. (2018). Assessing environmental literacy of university students: A case study of Shahid Beheshti University in Iran. *Applied Environmental Education and Communication, 18*(9), 1–18. https://doi.org/10.1080/1533015X.2018.1431163

Voulvoulis, N., & Burgman, M. A. (2019). The contrasting roles of science and technology in environmental challenges. *Critical Reviews in Environmental Science and Technology*, *49,* 1079–1106. https://doi.org/10.1080/10643389.2019.1565519

Wilson, R. A. (1996). Environmental education programs for preschool children. *The Journal of Environmental Education, 27*(4), 28–33. https://doi.org/10.1080/00958964.1996.9941473

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

World Health Organization (2020). *WHO global strategy on health, environment and climate change: the transformation needed to improve lives and wellbeing sustainably through healthy environments*. World Health Organization. https://apps.who.int/iris/handle/10665/331959

Yalcin, F. A., & Yalcin, M. (2017). Turkish primary science teacher candidates' understandings of global warming and ozone layer depletion. *Journal of Education and Training Studies*, *5*(10), 218–230. https://doi.org/10.11114/jets.v5i10.2225

Yurttaş, G. D., & Sülün, Y. (2010). What are the most important environmental problems according to the pre-service science teachers? *Procedia-Social and Behavioral Sciences*, *2*, 3412–3416. https://doi.org/10.1016/j.sbspro.2010.03.244

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CONSTRUCTING CORE TEACHING COMPETENCY INDICATORS FOR SECONDARY SCHOOL SCIENCE TEACHERS IN CHINA

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Abstract. *Science teachers play a key role in successfully implementing science education reforms and providing all students with meaningful science learning opportunities. Therefore, what core teaching competencies do science teachers need to have in their practice? This study uses fuzzy Delphi technique and Analytic Hierarchy Process to approach the above problems. Experts from Chinese universities, secondary schools and educational research institutions were invited to participate in two rounds of Delphi process. The research results show that the four domains of core teaching competencies of science teachers and their 21 competencies have high content validity. Additionally, it can be concluded that the weights of core competencies of making learning objectives, raising pedagogical questions, stimulating learning motivation and analyzing course content ranked high, while the weights of core competencies of using information technology and multimedia, evaluating practical work, and presenting research results have received less attention. It is believed that the results of this study can enlighten the education reform of science teachers and promote the professional development of pre-service/in-service science teachers.*

Keywords: *teaching competence, science teacher, fuzzy Delphi, Analytic Hierarchy Process*

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Introduction

With the deepening of globalization and the rapid development of science and technology in today's world, the competition among various countries is increasingly intensified. In order to cope with the increasingly complex situations and problems in life and learning in the 21st century, students need to acquire and master the key competencies needed to future professions and careers during school (OECD, 2005, 2006; Tiana et al., 2011; Yao & Guo, 2018). The construction of teacher core competences is the key step to promote the development of core competences of students, and it is also the key to cultivating outstanding citizens who can adapt to globalization in the future. Many studies have shown that teacher competence has a positive effect on the formation of students' key competences (AACTE, 2016; Caena, 2014; Distler, 2007; Gordon et al., 2009). For example, Distler (2007) found that teachers' competences in organizing problem-based learning and implementing evidence-based teaching practice have a positive effect on critical thinking and clinical practice competences of nursing students. In report *Key Competences in Europe*, the Education and Culture Department of the European Commission pointed out that in the practice of competence-oriented curriculum reform, schools that have implemented quite successfully, a useful experience is that they all focus on the development of core teacher competences. In 2014, during the drafting of the *Education and Training: 2020 Plan*, Francesca, who was responsible for the research on teacher professional development, also realized that in terms of improving student learning and improving school effectiveness, teacher competence is always placed at the core, and excellent teachers should have the ability to cultivate excellent global citizens (Caena, 2014).

In the field of science education, we are in an era of striving for all students to achieve scientific literacy (one of the main goals of science education) (Bybee, 1995; NRC, 1996, 2012). In science teaching practice, the competent science teacher is the decisive factor for the success of students'

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science learning and the development of scientific key competences (Shaharabani & Tal, 2016). However, current school science disciplines, especially secondary school physics and chemistry, are not welcomed by students (Hofstein et al., 2011). This undoubtedly brings many difficulties to the teaching practice of science teachers and leads to the decline of the quality of science learning, and students' scientific literacy is ultimately difficult to be effectively developed. Davis et al. (2006) pointed out that science teachers in current school need to deal with the following challenges: understanding scientific disciplines and its subject matter; understanding of learners; understanding of teaching practice; understanding of learning environments and subject specialization.

Therefore, what are the key competences that a competent science teacher should have in dealing with these challenges and dilemmas? Eichinger (1992) pointed out that a competent science teacher should have interest in science; be competent in experimental demonstration and teaching; design experiments based on limited instruments and chemicals; have willingness to take time to prepare experiments and demonstrations, etc. Champagne and Hornig (1987) considered that a qualified science teacher should teach students to be productive and responsible citizens and generate student interests in science and prepare students to enter science as career. Bruce and Leonie (2006) found that the characteristics of the effective science teacher mainly include teaching methods, communications, enthusiasm, organizations, relationships between teacher and student, assessment of students, etc. Additionally, countries such as the United States and Australia have also enacted professional standards for the core teaching competencies of science teachers in secondary schools. For example, in *National Science Education Standards* (NSES), American science teachers' core teaching competencies such as implementation of inquiry teaching, evaluation of students' inquiry ability and educational research got attention (NRC, 1996). And Australian *National Professional Standards for Highly Accomplished Teachers of Science* pays special attention to science teachers' evaluation ability, inquiry-based teaching practice, digital literacy, and educational research skill as well (ASTA, 2002).

However, unlike the United States and Australia, which issued professional standards of core competences for science teachers, there is no textual standard for science teachers in China except a universal standard for both primary and secondary school teachers. Moreover, there are few studies on the core teaching competencies of secondary science teachers. Since the majority of secondary science teachers in mainland China are subject teachers (e.g., physics teacher, chemistry teacher) rather than integrated science teachers who usually undertake at least two science disciplines), the research on physics or chemistry teachers is much more common than that of integrated science teachers. Therefore, research on the core competences of middle school science teachers is of great significance to the regions that implement integrated science education in mainland China. It not only promotes the professional development of teachers in the regions where integrated science education is implemented, but also contributes to the construction of a core competences system and professional standard for science teachers in the future.

Theoretical Framework and Literature Review

The concept of *competence* aims at transferring attention from knowledge (especially declarative knowledge) to the application of skills, and it is the ability of the individual to apply knowledge and skills on a certain degree of independence and autonomy (Wuttke & Seifried, 2017). Mulder (2012) believed that competence has the following specific characteristics: it is the ability, talent, and potential of a person; it is a combination of knowledge, skills, and attitudes; it is a necessary condition for an individual to make an achievement; etc. McClelland (1973) argued that the school performance does not seem to have a real power in predicting real-world competence, that is, traditional intelligence tests do not always predict future job success. For a company or an organization, what makes the concept of competence really valuable is not trying to ensure that everyone is competent for every job, but to find an organization/job that suits the individual. Spencer and Spencer (1993) put forward the *Iceberg Model* of competence which consists of knowledge, skills, self-concept, traits, and motivation. The *Iceberg Model* provides a wider understanding of the connotation and characteristics of 21st century competence in various vocations and professions. Taking teacher competence as an example, it involves the sum of psychological qualities such as the knowledge, skills, and dispositions that teachers need to complete teaching tasks, and it reflects the potential of effective behaviors shown by teachers in response to specific pedagogic situations (Caena, 2014).

It should be noted that the term *competence* or *competency* lacks a consistent meaning in both the British and European linguistic traditions (Weinert, 2001). But there are also some basic consensuses, for example,

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that “competence” (plural “competences”) is a broader term, while “competency” (competencies) refers to the different components of competence (Blömeke et al., 2015). It can be found that *competence* describes a complex feature from a holistic perspective, while *competency* has an analytical standpoint. In addition, both terms agree that a competence framework recognizes the nature of the performance requirements of certain fields in the real situation (Blömeke et al., 2015). Therefore, the definition of competence must start from the analysis of the real work context or education situation. Blömeke et al. (2015) considered competence as a horizontal continuum, which assumes that the whole is the sum of its (weighted) parts and divides competence into multiple constituents (latent abilities, skills) needed for competent performance. This study focuses on key teaching competencies (teaching competency), which places emphasis on components of competence from analytical stance.

Competencies can be understood as cognitive abilities and skills, which focuses on categorization and characterization of specialized cognitive competencies. Key Competencies of science teaching refer to clusters of cognitive perquisites that must be available for a science teacher to plan, enact and evaluate his/her science teaching practice. Undeniably, the term competence includes knowledge, dispositions, domain-specific skills, which cover all of a person’s cognitive resources. Weinert (2001) pointed out that such a broad definition also has greatest disadvantage which people have confronted and have not been solved in the hundred years of scientific psychology: the integration of complementary classification and concrete performance of competence and knowledge. Therefore, the domain of science teaching competencies can be specialized and narrowly defined or very openly and widely defined.

In science education, pedagogical content knowledge (PCK) is an important part of science teachers’ knowledge system. Park (2008) considered that PCK comes from teaching practice and science teachers apply PCK in their teaching practice and emphasized that PCK includes teachers’ understanding and implementation. Veal and Makinster (1999) believed that PCK is competence that science teachers use a variety of strategies and evaluation methods to *translate* subject knowledge for different groups of students under the conditions of understanding the learning context, culture, and social constraints. Carlson and Daehler (2019) refined PCK in science education from the aspects of collective PCK (cPCK), personal PCK (pPCK), and enacted PCK (ePCK), which integrated PCK (e.g., discipline, topic, concept) and competence (planning, enacting, reflecting, and evaluating) based on the educational context and practice. Obviously, different scholars have different understandings on whether PCK is knowledge or competence. After sorting out various viewpoints, this study believes that PCK is the knowledge owned by teachers, and only after teachers have the knowledge of students’ understanding, teaching strategies and evaluation, can they demonstrate those core competencies in the teaching plan or the instruction enactment. And science teachers can successfully apply core teaching competencies across a maximum number of different tasks based on their classroom experiences and context.

To sum up, *teacher competence* involves implicit and explicit knowledge (e.g., PCK, subject matter, assessment knowledge), cognition, practical skills, and dispositions (motivation, belief, value orientation and emotion), and *teaching competency* reflects the core competencies of secondary science teachers to cope with various daily teaching situations. The former describes a complex feature from a holistic perspective, while the latter places emphasis on components of competence from analytical stance. Besides, in order to clarify the relation among teaching competency, teacher competence and competence, Figure 1 is presented. As can be seen in Figure 1, in terms of the subordination relation among them (teaching competence, teacher competence and competence), the former is subordinate to the latter respectively, and the latter involves a broader and systematic professional concept, which is universal and general. For example, Sudirman (2017) divided teacher competence into teaching/pedagogical competency, individual competency, social competency, and professional competency. Similarly, Green and Osah-Ogulu (2003) identified three categories of teacher competence: intellectual competency, environmental competency, and pedagogical competency. As the mentioned above, the scope of the concept of teacher competence is wider than that of teaching competency.

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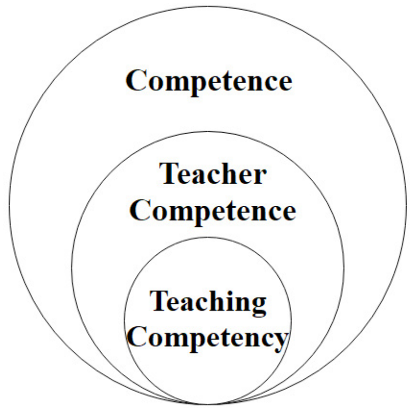
Figure 1
The Subordination among Competence, Teacher Competence, and Teaching Competency



Teacher Competence

The European Teacher Competence Framework (ETCF) describes the concept of teacher competence as follows: *it involves implicit and explicit knowledge, cognition, practical skills, and dispositions (such as motivations, beliefs, values and emotions); it can meet the complex needs of teachers (for example, teachers can make them behave professionally and appropriately in specific situations by mobilizing psycho-social resources); it can ensure that teachers carry out their tasks effectively and the tasks were completed efficiently, and can continuously represent the specific level of individual achievement* (Caena, 2014). Teacher competence is interdisciplinary and multifunctional and plays an important role in the realization of many important goals and helps individual deal with different tasks, and transfer in unfamiliar situations (Caena, 2014).

Many scholars have defined and studied teacher competence. For example, Bieri (2011) proposed that teacher competence should include five dimensions such as communication, cooperation, self-confidence, motivation, and fact-finding. Kaendler et al. (2015) divided teacher competence into professional knowledge, teacher beliefs, the ability to plan interaction, monitor, support, and consolidate interaction, and reflect. Zhu et al. (2013) validated core competences related to teachers' innovative teaching, and carried out four competences: learning competence, educational competence (such as responsibility, love, sensitivity and so on), social competence and technological competence. It can be found that the definition and connotation of teacher competence is comprehensive and integrative (such as knowledge, skills, behavior, skills, self-concept, dispositions, etc.), and it is a complex psychological quality that must be mastered for individual cognition, social interaction, and professional achievement (Bieri & Schuler, 2011; Mulder, 2001; Wuttke & Seifried, 2017).

Teaching Competency

Teaching competency is directly related to pedagogical skills, and it is all the repertoire that a teacher must master in dealing with different teaching situations (Caena, 2014). Tigelaar et al. (2004) pointed out that the traditional teaching competency framework mainly involves teaching methods, demonstrating skills, guidance and suggestion skills, and skills of designing course materials. Many researchers have conducted empirical studies on teaching competency. For example, Bawane and Spector (2009) divided teaching competencies into designing strategies, selection of appropriate learning resources, implementing teaching strategies, encouraging students to participate in cooperation and helping students maintain motivation. Gilberts and Lignugaris-Kraft (1997) presented five categories in instruction competencies such as preparation for specific instructional activities, presentation of material, feedback and praise, interactive assessment, and effective use of time.

In addition to the above-mentioned research on teaching competencies, there are also many studies on teaching competencies from the perspective of teachers' roles. For instance, Tigelaar et al. (2004) constructed teaching competency through the Delphi method from the perspective of roles: teacher as individual, subject

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knowledge expert; facilitator of learning (such as learning evaluation) and scholar/lifelong learners. Carril et al. (2013) divided teaching competencies into the following five roles: designers and developers (designing teaching plans and strategies, developing learning resources, implementing teaching plans and strategies, and designing evaluation activities); subject content experts (developing courses); mentors (organizing and promoting various teaching practices); professionals (communication, update knowledge, attitude, and participate in professional development projects). It can be found that studies on teaching competencies all attach importance to core skills before or during the teaching practice of science teachers, such as preparation and planning skills, implementation and practical skills, evaluation skills, etc.

Science Teacher Competence

Since the 1960s, many scholars have studied the competence of science teacher (Alake-Tuenter et al., 2012; Butzow & Qureshi, 1978; Mulder, 2014; Spore, 1962; Tulloch, 1986; Green & Osah-Ogulu, 2003). Butzow and Qureshi (1978) got 12 indicators of competence of science teacher: knowledge, good relationship between teachers and students, identification of individual differences, creation of vivid classrooms, subject competence, instructional design, critical thinking, etc. Alake-Tuenter et al. (2012) considered competence of science teacher as an individual comprehensive performance-oriented capacity, including a large number of knowledge structures and cognition, effective and necessary mental abilities, attitudes and values. And these elements play a role in performing tasks, solving problems, and in a profession, organization, position, or role. Alake-Tuenter et al. (2013) identified three core elements of competence of science teacher including subject matter knowledge, pedagogical content knowledge, and attitude. For another example, Sedibe et al. (2014) conducted structured interviews to explore the competence of science teacher in senior township schools in Soweto, Gauteng Province, and the results showed that these science teachers highly identify with the following three competences: enthusiasm for science teaching, qualifications and experience of science teaching, and supportive teaching materials. Through the above literature, it is found that the competence of science teacher mainly involves the following components: knowledge, teaching skills, attitudes, values and so on.

Science Teaching Competency

In addition to the research on the competence of science teacher, there are scholars who have conducted empirical research on the teaching competencies of science teacher. De Putter-Smits et al. (2012) pointed out that the teaching focus of STEM disciplines or scientific subject matter should be intended to develop teaching competencies of science teacher. And teaching competencies in science education mainly include teaching practice, preparedness, engagement with students and learning of evaluation (Deacon et al., 2017). The Science Teacher Education Committee of the United States (1974) obtained 23 basic elements of teaching competencies of science teacher such as evaluating student achievement, selecting and designing teaching materials, clarifying courses and units of learning objectives, and directing practical work, etc. De Putter-Smits et al. (2012) divided the teaching competencies of science teacher into five dimensions: context handling, regulation, emphasis, design, and school innovation. Wu et al. (2018) developed a questionnaire to investigated science/math teachers' perceptions of their professional teaching competencies, which mainly include providing students a cooperative learning environment, capable of raising students' attitudes toward math/science, etc.).

Based on the above literature review, it can be found that the teaching competencies of science teacher studied by researchers mainly involved three domains: pedagogical design (such as analyzing course content and students, making learning objectives, designing activities, etc.), teaching implementation (such as organizing scientific inquiry, using information technology and multimedia, encouraging cooperation, etc.), and learning evaluation (evaluation of the learning process and feedback). In this study, the fourth domain of *teacher research* was added. McClelland (1973) stated that competence refers to the deep-level personal characteristics that can distinguish outstanding accomplishers from ordinary work. From this point of view, teacher research is an important domain of teaching competencies of science teacher. In *National professional standards for highly accomplished teachers of science,* the Australian Science Teachers Association points out that *highly accomplished science teachers are active in professional communities outside schools, writing articles for journals, participating in research projects*... Stenhouse (1981) proposed the concept of teacher research, that is, teachers conduct research on their own practice, teaching, and student learning in a systematic way. Zhu and Wang (2014) considered educational research ability as one of teachers' key

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competence. In order to avoid personal subjective judgments and predict which competences should be paid attention to in the teaching competencies of a science teacher, we chose the Delphi technique for this research.

Research Problem

However, as a topic in the field of science education research, the focus of science teacher mainly involves PCK (Shulman, 1986 &1987), views on nature of science (Lederman, 1992; Abd-El-Khalick & Lederman, 2000), dispositions (Flores, 2016), and few research studies on the core teaching competencies of science teachers (Ye et al., 2019). And even if it is competence research about science teacher, the research objects are mainly about elementary science teacher or pre-service science teacher (Deveci, 2016; Wu et al., 2018), and there are few studies for secondary school science teachers. Moreover, most of the research on (science) teacher competence only focuses on the acquisition and extraction of the competences components, instead of further comparing the relative importance (weights) of these competences to obtain more in-depth results and conclusions. In a word, unlike the international science education research that has always emphasized science courses, conceptual learning, and scientific literacy research, there is less attention paid to the research on the competence of secondary school science teachers (Ingersoll, 2011).

Given the above analysis and consideration, this study raised the following two questions:

(a) What are the core teaching competencies should secondary school science teachers possess?
(b) What is the relative importance (weights) among these core competences?

This study used fuzzy Delphi technique and Analytic Hierarchy Process to explore the above questions. Therefore, the study aimed to identify core competences related to science teaching that secondary science teachers should be equipped with through the authority decision processes by expert community. It is expected that the results of the study can enlighten the education reform of science teachers and promote the professional development of pre-service/in-service science teachers.

Research Methodology

The fuzzy Delphi technique is an improved experts' decision-making method that introduces the fuzzy mathematic theory into the Delphi research. There are many disadvantages in the implementation of Delphi technique. For example, the implementation period is too long, and it is costly to complete the entire research through multiple rounds of repeated surveys. Moreover, the answers and feedback of experts are ambiguous and uncertain. In order to solve these problems, Murray et al. (1985) combined the Delphi technique and fuzzy set to reduce the ambiguity of the Delphi technique. Additionally, Kaufmann and Gupta (1988) proposed another more complete fuzzy Delphi process, which uses fuzzy set theory and requires participants to give three evaluation values (conservative value, optimal value, and optimistic value), and then form a Triangular Fuzzy number (TFN) and calculate their geometric means. The advantage of TFN is that it can make up for the occurrence of extreme values and enhance the effect of indicator selection (Ishikawa et al., 1993). And fuzzy Delphi technique usually requires only one or two round consultation based on Triangular Fuzzy number **(**Lin & Lu, 2013; Saido et al., 2018**).**

Analytic Hierarchy Process is a decision-making method used to deal with multi criteria problems and can handle tangible and intangible factors. Its main feature is that it can reasonably combine qualitative and quantitative decision-making, and hierarchize the decision-making process based on individual thinking and psychological patterns and can summarize multi-factor problems or complex multi-criteria into a hierarchical structure. Saaty (1977) pointed out that the hierarchy is a representative structure of complex problems in a multi-level hierarchical structure. By using a hierarchical structure, you can describe a specific problem in different groups, and then organize it into a hierarchical structure, so that the problem becomes more structured and systematic. Analytic Hierarchy Process is the result of the selection criteria and is dominated by the deepest sub-criteria. Moreover, it attaches importance to validity. If the inconsistency exceeds a certain threshold, the decision-maker will make a new choice from various standards and alternatives.

Participants

The selection of experts is the key step to ensure the quality of Delphi research (Wan & Bi, 2020). Before starting the consultation and investigation formally, this research explained to each expert the purpose and necessity

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of this research and the time required to participate in the research and promised that their participation in this project must volunteer, and to ensure that the experts' personal information is kept confidential and will not be disclosed to others or other purposes. The number of experts may vary from 10 to 50 (Saido et al., 2018; Wan & Bi, 2020). In this study, a total of 30 experts was invited successfully, including 10 science teachers, 8 science education administrators, and 12 university professors (See Table 2). All experts at least meet the following three or more criteria: (1) professor title; (2) at least 20 years of working experience in secondary school science teaching, science learning research or science teacher research; (3) domestic and foreign papers or academic works in science education; (4) principal or vice principal; (5) experience of trainer in science teachers' professional development. The collected expert questionnaires were reviewed. A total of 28 questionnaires met the response requirements, and the effective rate of the questionnaires was 93.33%. The invalid questionnaire was judged as the obvious regularity of the answers, and the answers did not conform to the logic and requirements of this study (for example, the three types of values must conform to the minimum value ≤ the optimal value ≤ the maximum value).

Table 1
Demographics of 30 Experts

Region	Gender		Seniority		Title
Province/City	Male	Female	20-30	≥30	Professor
Anhui	2	1	1	2	3
Beijing	3	2	0	5	5
Fujian	2	0	0	2	2
Hainan	1	0	0	1	1
Jilin	1	0	1	0	1
Jiangsu	3	0	2	1	3
Jiangxi	1	0	0	1	1
Shanghai	1	0	0	1	1
Shan'xi	1	0	1	0	1
Shandong	6	2	4	4	8
Shanxi	0	1	1	0	1
Zhejiang	3	0	2	1	3
Total	24	6	12	18	30

Instruments

The items of instruments in this study were selected based on literature reviews and existing research results (Table 2). Specifically, the first domain (Pedagogical Design) mainly involves competences: analyzing course content (ACC), analyzing students (AS), making learning objectives (MLO), arranging procedures and steps (APS), designing activities (DA), and choosing strategies and tools (CST). The second domain (Teaching Implementation) includes stimulating motivation (SM), establishing learning context (ELC), directing practical work (DPW), organizing scientific inquiry (OSI), using information technology and multimedia (UIM), and encouraging cooperation (EC). The third domain (Learning Evaluation) includes evaluation of learning process (ELP), evaluation of academic achievement (EAA), evaluation of practical work (EPW), and feedback of evaluation (FE). And the fourth domain (Teacher Research) mainly covers competences such as raising questions (RQ), collecting data (CD), developing plan (DP), implementing protocols (IP), and presenting research results (PRR).

The instruments in this study were mainly divided into two categories: the fuzzy Delphi questionnaire and the Analytic Hierarchy Process questionnaire. Except for differences in format and structure, the contents of the two types of questionnaires are basically the same, and there are no major differences. The fuzzy Delphi questionnaire adopts 0-10 rating mode, and the participants need to give three values for each item independently. Analytic

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Hierarchy Process questionnaire adopts the scoring mode of 1-9. Participants need to compare each pair of items in pairs and give the relative importance value. The questionnaires in this study consist of 21 items, and the structure of the questionnaire includes the following four parts: introduction, filling instructions, filling examples and filling items. Based on the questionnaire data of 30 experts, the overall Cronbach alpha coefficient of the questionnaire is .919, indicating that the scale had a high reliability.

Data Analysis

Fuzzy Delphi technique

The data processing and analysis of fuzzy Delphi questionnaires mainly aims to check whether the opinions among the experts are consistent and calculate the value of the consensus significance G^{j} for each criterion. It includes the following three steps: **Step 1:** If ≤, it means that the expert group has consensus on the item. **Step 2:** If>, and the gray zone interval value (Z^{i}=-) is smaller than the interval value (*M*=-). It shows that in the presence of a tiny gray fuzzy space, but the experts who give extreme opinions will not be too different from other experts, so there is no divergence of opinions. **Step 3:** If>, and the gray zone interval value (Z^{i}=-) is greater than the interval value (*M*=-). It indicates that some experts put forward extreme opinions very different from others. Therefore, it is necessary to conduct another round of questionnaire survey on these evaluation items that have not reached convergence. After two rounds questionnaire surveys, if the evaluation item fails to reach the convergence standard, it will be deleted.

Analytic Hierarchy Process

Analytic Hierarchy Process analysis generally goes through the following steps: **Step 1:** Construct an Analytic Hierarchy Process questionnaire to collect data (this was done with the help of fuzzy Delphi technique). **Step 2:** Calculating the geometric means based on Analytic Hierarchy Process questionnaires and constructing the total judgment matrix. The purpose of this section is to integrate the opinions of all the experts. **Step 3:** Consistency testing is necessary to use Analytic Hierarchy Process research, so it is necessary to determine whether the pairwise comparison matrix is consistent. The indicators mainly involve the use of Consistency Index (*CI*) and Consistency Ratio (*CR*). *CR* is used to measure how far the decision-makers' judgment is from the critical value of the consistency of fitting. *CR* is obtained by dividing the consistency index (*CI*) by the random index (*RI*). If $CR < 0.1$, it means that the actual judgment matrix has high consistency (Saaty, 1977). **Step 4:** Determine the global weight of each domains and behavioral indicators accordingly.

Table 2
Core Teaching Competencies and Characteristics for Secondary School Science Teacher

Domains	Competences	Alake-Tuenter et al. (2012)	Aydeniz & Dogan (2016)	Beasley (1982)	Bell & Cowie (2001)	Beyer & Davis (2012)	Butzow & Qureshi (1978)	Castle (2006)	Cheng (2014)	Davis et al. (2011)	Dobber et al. (2012)	Forbes & Davis (2010)	Hensiek et al. (2017)	John (2006)	Klein & Jun (2014)	Simpson & Brown (1977)	Stenhouse (1981)	Tulloch (1986)	Willegems et al. (2017)	Wu et al. (2018)	Zhang et al. (2017)	Zhu et al. (2013)
Pedagogical Design	ACC					○			○					○	○						○	○
	AS					○			○	○				○	○						○	
	MLO					○			○	○				○	○						○	
	APS					○															○	○
	DA													○							○	
	CST					○			○					○	○						○	○

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Domains	Competences	Alake-Tuenter et al. (2012)	Aydeniz & Dogan (2016)	Beasley (1982)	Bell & Cowie (2001)	Beyer & Davis (2012)	Butzow & Qureshi (1978)	Castle (2006)	Cheng (2014)	Davis et al. (2011)	Dobber et al. (2012)	Forbes & Davis (2010)	Hensiek et al. (2017)	John (2006)	Klein & Jun (2014)	Simpson & Brown (1977)	Stenhouse (1981)	Tulloch (1986)	Willegems et al. (2017)	Wu et al. (2018)	Zhang et al. (2017)	Zhu et al. (2013)
	SM	○				○										○				○		
	ELC	○																		○		
Teaching Implemen-tation	DPW					○						○										
	OSI	○		○		○						○				○				○		
	UIM			○		○						○				○						○
	EC	○				○										○				○		○
	ELP		○		○		○											○				○
Learning Evaluation	EAA				○		○											○				○
	EPW												○									
	FE		○	○			○						○									
	RQ							○									○		○			○
	CD							○			○						○		○			○
Teacher Research	DP										○						○		○			
	IP							○									○		○			
	PRR							○			○						○		○			

Research Results

Consensus Analysis of the Experts

Table 3 and Table 4 shows the results of the fuzzy Delphi survey of the four domains and their core competences in science teaching accordingly. The calculation of fuzzy Delphi questionnaire shows that, taking "T1-1" as an example, the minimum and maximum of the most optimistic value () given by the expert community on the domain of pedagogical design is 8 () and 10 () respectively. Then, calculate the arithmetic mean of the experts' of the competence, which is 9.00, and the standard deviation (*SD*) is 0.49, and delete extreme values that greater than or less than twice the *SD* (9.00±0.98). In this example, experts' optimistic values are all within twice the *SD*, and so all items are retained. Then calculate the geometric mean value to establish the triangular fuzzy number = (8, 9.00, 10) for the most optimistic value. Similarly, establish the triangular fuzzy number = (5, 6.39, 8) for the most conservative value. Then, the *Grey Area Method* is used to test whether the expert community has reached a consensus on item T1-1. In this example (T1-1), there is no overlap between the two triangular fuzzy numbers (≤), indicating that there is a consensus of the expert opinion interval value, and it turned out items T1-1 have reached convergence. Besides, items like T1-3, T1-4, T1-5, T1-6, T2-1, T2-2, T2-3, T2-4, T2-5, T3-2, T3-4, T4-1, and T4-4 also meet the above requirements and retain these items. Currently, the consensus degree value between experts: G^i=()/2=7.70.

However, the two triangular fuzzy numbers of T1-2, T2-6, T3-1, T3-3, T4-2, T4-3 and T4-5 overlap, and the gray area (Z^i=-) is less than the interval between the expert's geometric mean of "the most optimistic value" and "the most conservative value" (M^i=-), i.e., ($Z^i<M^i$), indicating that the opinion interval value of each expert has no consensus section. It means that although the opinion interval value of each expert has no consensus section, the two experts who gave extreme value opinions (the most conservative value in optimistic value and the most optimistic value in conservative value) did not differ too much from other experts, leading to diverging opinions. At this time, the consensus degree G^i=/. It can be found from Table 3 that the expert consensus value of these 7

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items is between 7.35 and 7.50. The threshold value of G^i in this paper is set to 6.5, which has been accepted by more than 80% of experts.

Table 3
Report of Four Domains of Core Teaching Competencies of Science Teachers

Code	Domains	O^i_L	O^i_U	C^i_L	C^i_U	O^i_M	C^i_M	M^i	Z^i	M^i- Z^i	G^i
T1	Pedagogical Design	7	10	4	7	9.02	6.10	2.92	0	2.92	7.56
T2	Teaching Implementation	7	10	4	7	9.09	6.13	2.96	0	2.96	7.61
T3	Learning Evaluation	7	10	3	7	8.59	5.88	2.71	0	2.71	7.24
T4	Teacher Research	7	10	3	7	8.59	5.87	2.72	0	2.72	7.13

Determine the Weights of All Domains and Competences

Table 5 shows the judgment matrix constructed by experts for the four domains of science teaching competence: for example, the importance of pedagogical design was 1.28 times that of teaching implementation, and the importance of teacher research was 2.3193 times that of learning evaluation, and the importance of teaching implementation was 2.7473 times that of learning evaluation, and so on. Finally, through the weights' average statistical results, it can be seen that the weights of the four core domains of science teaching competence were: pedagogical design (36.69%) > teaching implementation (28.67%) > teacher research (24.20 %) > learning evaluation (10.44%).

Table 4
Report of Core Teaching Competencies of Science Teachers

Domains	Competences	O^i_L	O^i_U	C^i_L	C^i_U	O^i_M	C^i_M	M^i	Z^i	M^i- Z^i	G^i
Pedagogical Design	T1-1	8	10	5	8	9.00	6.39	2.91	0	2.91	7.70
	T1-2	7	10	4	8	8.75	6.01	2.74	1	1.74	7.47
	T1-3	8	10	5	8	9.24	6.58	2.66	0	2.66	7.91
	T1-4	9	10	5	8	9.35	6.68	2.62	-1	3.62	8.02
	T1-5	8	10	5	8	9.19	6.63	2.56	0	2.56	7.91
	T1-6	7	10	5	7	8.64	5.69	2.95	0	2.95	7.12
Teaching Implementation	T2-1	8	10	5	8	9.41	6.54	2.87	0	2.87	7.98
	T2-2	8	10	5	8	9.33	6.48	2.85	0	2.85	7.91
	T2-3	8	10	5	8	9.33	6.57	2.73	0	2.76	7.95
	T2-4	8	10	4	8	9.32	6.39	2.93	0	2.93	7.86
	T2-5	7	10	4	7	8.57	5.23	3.24	0	3.24	6.93
	T2-6	7	10	4	8	8.82	5.94	2.88	1	1.88	7.47
Learning Evaluation	T3-1	7	10	4	8	8.45	5.60	2.85	1	1.85	7.38
	T3-2	7	10	5	7	8.30	5.78	2.52	0	2.52	7.04
	T3-3	7	10	3	8	8.75	5.98	2.77	1	1.77	7.46
	T3-4	8	10	5	8	8.87	6.18	2.69	0	2.69	7.53
Teacher Research	T4-1	8	10	4	8	9.01	6.15	2.86	0	2.86	7.58
	T4-2	7	10	4	8	8.53	5.70	2.83	1	1.83	7.40
	T4-3	7	10	3	8	8.45	5.60	2.85	1	1.85	7.38
	T4-4	7	10	5	7	8.44	5.78	2.77	0	1.77	7.11
	T4-5	7	10	5	8	8.54	6.13	2.41	1	1.41	7.45

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Table 5
Weight Analysis of Four Domains

Domains		T1	T2	T3	T4	Weight	Rank
Pedagogical Design	T1	1	1.2800	3.5165	1.5162	36.69%	1
Teaching Implementation	T2	0.7813	1	2.7473	1.1846	28.67%	2
Learning Evaluation	T3	0.2844	0.3640	1	0.4312	10.44%	4
Teacher Research	T4	0.6595	0.8442	2.3193	1	24.20%	3

CR< 0.1.

Table 6 shows the ranking of the weights of 21 competences for core teaching competencies of science teachers in middle schools, including the intra-group weights and overall weights, as well as the intra-group rankings and overall rankings.

In the domain of pedagogical design, the weights of key competences ranked below: make learning objectives (27%) > analyze course content (22%) > analyze students (20%) > design activities (13%) ≈ arrange procedures and steps (13%) > choose strategies and tools (5%). The rank of weight in developing educational **objectives**, analyzing course content and analyzing students was in the top 3, and their weights in the group all exceed 20% accordingly, indicating the importance of these elements in the teaching preparation stage before the teacher's teaching implementation. Moreover, the competence of developing educational objectives (9.99%) ranked first among the 21 competences, and the competence of analyzing course content and analyzing students also rank very high in the overall ranking.

Table 6
Weight Analysis of Overall Competences

Domains	Competences	Weight (%)	Rank	Overall Weight (%)	Overall Rank
Pedagogical Design CR< 0.1	Analyze course content	22	2	8.14	4
	Analyze students	20	3	7.40	5
	Make learning objectives	27	1	9.99	1
	Arrange procedures and steps	13	5	4.81	
	Design activities	13	4	4.81	
	Choose strategies and tools	5	6	1.85	
Teaching Implementation CR< 0.1	Stimulate motivation	31	1	8.99	3
	Establish learning context	24	2	6.96	
	Direct practical work	12	4	3.48	
	Organize scientific inquiry	20	3	5.80	
	Use information technology and multimedia	4	6	1.16	
	Encourage cooperation	9	5	2.61	
Learning Evaluation CR< 0.1	Evaluation of learning process	26	2	2.60	
	Evaluation of academic achievement	32	1	3.20	
	Evaluation of practical work	19	4	1.90	
	Feedback of evaluation	23	3	2.30	

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Domains	Competences	Weight (%)	Rank	Overall Weight (%)	Overall Rank
Teacher Research CR< 0.1	Raise questions	41	1	9.84	2
	Collect data	11	4	2.64	
	Develop plan	22	2	5.28	
	Implement protocols	16	3	3.84	
	Present research results	10	5	2.40	

In the domain of teaching implementation, the weights of key competences ranked below: stimulate motivation (31%) > establish learning context (24%) > organize scientific inquiry (20%) > direct practical work (12%) > encourage cooperation (9%)> use information technology and multimedia (4%). The rank of weight in stimulating motivation, establishing learning context and organizing scientific inquiry was in the top 3, and their weights in the group all exceeded 20%, indicating the importance of these elements in the teaching practice of science class. Moreover, the competence of stimulating motivation (8.99%) ranked the third among the 21 competences, indicating the importance of stimulating students' motivation in teaching practice.

In the domain of learning evaluation, the weights of key competences ranked below: evaluation of academic achievement (31%) > evaluation of learning process (26%) > feedback of evaluation (23%) > evaluation of practical work (19%). It can be seen that the evaluation of scientific learning achievements is much more important than other factors, and the emphasis on practical work and evaluation feedback are relatively insufficient. Additionally, the weights of the four key competences in the evaluation domain were relatively low in all 21 competences, which reflects the distinct disadvantage of evaluation in the current Chinese science teaching to a certain extent.

In the domain of teacher research, the weights of key competences are ranked below: raise questions (41%) > develop plan (22%) > implement protocols (23%) > collect data (16%) > present research results (11%) > collect data (10%). It can be seen that raising questions is much more important than other factors, and the emphasis on presenting research results is relatively insufficient. Moreover, the competence of raising questions (9.84%) ranked second among the 21 competences, indicating the importance of raising questions in pedagogical research.

Experts' Views on Teaching Competencies of Science Teacher

Some experts put forward their opinions and suggestions on the specific content of core teaching competencies during the fuzzy Delphi research. These recommendations are sorted out and collated, which provides an important basis for the follow-up investigation of Analytic Hierarchy Process. For example, Expert ZKL pointed out that *secondary school science teachers can use the novel information technology in science classrooms*. And expert YBJ believes that *secondary school science teachers should be able to integrate skillfully science and technology into the scientific learning environment*. These two experts pay special attention to the competence of science teachers to integrate science and technology with science teaching practice. Taking information and communication technology as an example, the rapid development of internet technology in the 21st century has promoted the popularization of information and communication technology in science teaching and learning. Information and communication technology not only enriches the learning environment of science classrooms, but also puts forward a more comprehensive ability demand for science teachers to integrate educational technology and teaching practice (Kadioglu-Akbulut et al., 2020). Science teachers with digital literacy must not only cultivate students' information and communication literacy, but also help students' peer collaboration and problem solving in the internet environment, which will ultimately enable students to develop into innovative and creative 21st century learners (Alt, 2018). Expert DYX states that *secondary school science teachers should be able to make some innovative practical works*, and WQH also considers that *improvement and innovation of demonstration experiments is the important competence that secondary school science teachers need to possess*. It can be found that both experts agree that secondary school science teachers' experimental ability is very important. The research of science teachers' practical work has always been a key direction in the research field of science teachers, and it has received the common attention and attention of scholars in different science education fields.

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Discussion

Science teachers play a key role in successfully implementing science education reforms and providing all students with meaningful science learning opportunities (Chin, 2006). Although the research on improving and enhancing the classroom teaching efficiency of middle school science teachers has received extensive attention in the past few decades, front-line science teachers still face many problems and difficulties (Davis et al., 2006). Undoubtedly, science teachers are the most dominant intersection between science curriculum and the improvement of individual scientific literacy. As an important part of the competence structure of science teachers, teaching competence is an indispensable capacity for science teachers to implement and carry out classroom teaching. For example, the Analytic Hierarchy Process results showed that the weights of learning evaluation and teacher research, as well as their core competences have low weights. However, the weights of pedagogical design and teaching implementation, as well as their core competences, are much higher.

Firstly, in the domain of pedagogical design, which ranks first among the four domains. The domain of pedagogical design represents the ability of science teachers to connect teaching theory with teaching practice activities and has a potential impact on the development of students' scientific capacities such as scientific argumentation and scientific reasoning (Knightbardsley & Mcneill, 2016). Specifically, it can be seen from Table 6 that the competence of making learning objectives ranks first among the six core competences, which is consistent with the existing relevant research results. For example, Zhang et al. (2017) found that pre-service biology teachers performed significantly better than biological technology students (non-teacher) in making learning goals ($p<.05$), but there is no significant difference in other core competencies in the domain of instructional design. Additionally, Klein and Jun (2014) surveyed 82 teachers with master's or doctoral degrees in instructional system of Florida State University, and the result turned that none of the respondents considered aligning objectives and preparing goals as unimportant, while more or less some of the subjects considered other competence indicators in the field of instructional design as unimportant. As one of the competences of teaching design, setting learning objectives is an indispensable skill for science teachers in the process of teaching design. Beyer and Davis (2012) also pointed out making learning goals and establishing lesson purpose play a significant role in pedagogical design for science teacher.

Secondly, in the domain of teaching implementation, it can be seen from Table 6 that the competence of using information technology and multimedia, encouraging cooperation, and directing practical work ranks in the bottom three, respectively. To a certain extent, this reflects the ignorance of the importance of these competences by science teachers in mainland China. Taking the using information technology and multimedia as example, it's not just about the teachers' ability to use digital resources, and it's about cognitive skills and social emotional skills involved in performing tasks and solving problems in a digital instructional environment (Van Laar et al., 2017). International organizations attach great importance to the development of teachers' information technology competence. For example, UNESCO promulgated an information technology Competency Framework for Teachers (ICT-CFT) in 2008 and issued the second edition of ICT-CFT in 2011, which aims to help different countries develop national level teacher information technology competence training strategies and standards. However, the weight of using information technology and multimedia in the six core competences is only 4% (see Table 6), far below the average weight of 17%. Deng et al. (2014) found that high school teachers' overall performance in using information technology is poor in China. The secondary school science curriculum is more closely related to science, technology, engineering, and the environment (Wan & Bi, 2020). Therefore, education administrators, teacher educators and science teachers need to take the competence of using information technology seriously, and deeply explore the professional development in using information technology and multimedia.

For another example, the competence of encouraging cooperation, its weight in the six core competences is only 9% (see Table 6), and far below the average weight of 17% as well. Cooperative learning emphasizes social interaction, which is a process of multi-directional in-depth communication between teachers and students, students and students, and is an effective learning method that has a positive impact on students' academic achievement (Guiller, Durndell, & Ross, 2008). However, the current school curriculum is loaded with too many concepts and knowledge, and students are often told that they only need to repeat and mechanically memorize these concepts, which makes it easy for students to understand them only at a superficial level. Cooperative learning is based on face-to-face social interaction, focusing on the development of critical thinking and communication skills. Guiller et al. (2008) stated that critical thinking is a collaborative learning process in which students construct knowledge through argumentation and discussion of various ideas and concepts. Traditional cooperative learning is carried

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out in the form of face-to-face social interaction. With the continuous popularization of internet technology, information technology and multimedia provide new ways to promote cooperative learning and the development of individual critical thinking and communication skills (Jang, 2014). Internet-based cooperative learning brings many conveniences to education (such as low cost, high efficiency, convenience, etc.), and with the continuous popularization of virtual reality technology, augmented reality technology, and holographic technology, internet-based cooperative learning brings more vivid and intuitive experience to individuals (Lopezperez et al., 2011). For teachers, the ICT-CFT framework points out that it is not enough for teachers to only possess information technology skills and impart it to students, and they also need to use information technology to help students become cooperative, problem-solving, and creative learners.

Thirdly, in the domain of learning evaluation, it is the field that science teacher least takes seriously (see Table 6). Similarly, the gap among its core competences is not very large overall, and these competences are not ranked high among all elements (see Table 6). According to the results of experts' weight assignment of teaching competencies of science teacher, science teachers in China do not attach great importance to individual science learning evaluation, and especially to its core competences such as the evaluation of students' practical work and their feedback. The biggest challenge in evaluating science learning is the cost (such as time, intelligence, labor, etc.) involved in designing and developing the evaluation. While higher-level skills such as critical thinking can be assessed using multiple-choice questions, science learning tools should not be limited to multiple-choice tests, but should also be used to assess creativity, and even use collaboration to complete the assessment (Pacific Policy Research Center, 2010). However, in China, especially high school science teachers, they often need to undertake a large number of teaching tasks. Generally, each teacher independently undertakes 3-4 classes of science teaching tasks (such as physics, chemistry, biology, etc.). The average number of students in each class will be around 50 or more, which brings great challenges to science teachers to carry out the assessment work for students' science learning. The earliest implementation of systematic and large-scale evaluations on scientific literacy in the world mainly includes the PISA and TIMSS, which mainly involves real contexts, subject matter, scientific attitude, and scientific practice and so on. At present, science academic testing in China has not formed a mature framework. The main reason lies in that science course and science ability assessment are not included in the core academic evaluation system, and science teaching has not got rid of the traditional teaching model. In view of this, science teacher in China should focus on students' scientific knowledge and ability from different dimensions in the evaluation, so as to achieve comprehensive evaluation and accurate interpretation to better guide learning and teaching.

Fourthly, in the domain of teacher research, the competence of raising question with the highest weight (41%) is four times more than the competence of presenting research result with the lowest weight (10%) (Table 6). Similarly, the weight of collecting data is almost as low as the weight of presenting research results, only 11%. This demonstrates that science teachers are more concerned with practical issues in the process of conducting pedagogical research, rather than collecting data or publishing research results. Such results are not very consistent with the results of many existing studies in the world. For example, in Castle's (2006) qualitative study, a first-grade teacher and a fourth-grade teacher both pointed out that they will actively write and publish pedagogical research papers, and they will be very happy to share and exchange their research results in teacher professional development projects. Dobber, Akkerman, Verloop and Vermunt (2012) emphasized the importance of collecting data and analyzing research results and incorporated the above-mentioned competences into the training practice of professional development of pre-service teacher pedagogical research. Teacher research means that teachers use existing knowledge and theories to guide their own teaching practice, and teachers can improve pedagogical design, teaching implementation and leaning evaluation through their study of teaching practice. The concept of *teacher as researcher* has become a professional terminology in the field of education, just as *teacher as practitioner* has been widely used in the past decade or so (Stenhouse, 1981; Moynihan et al., 2015).

Conclusions and Limitations

Compared with the science learning research that has been continuously published in journals in recent years, there are few reports on the science teachers in China. In this study, four domains and 21 core competences of science teaching practice were identified and verified based on the consensus among experts. Specially, the level-one domains mainly include *Pedagogical Design*, *Teaching Implementation*, *Learning Evaluation* and *Teacher Research*, and their corresponding 21 core competences not only passed the fuzzy Delphi convergence test, but obtained a high consensus of the expert community, indicating that the core competences have high validity. The

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results of this research are of great value to science teacher education and their professional development. Firstly, the competence indicators constructed by this research have a good reliability and can be used to evaluate and diagnose the competence performance of secondary science teachers. Secondly, these competency indicators can provide reference and enlightenment for the construction of the core competencies system and standards of science teachers in middle schools in China. In the future, there is still a lot of work worth doing. For example, teachers' knowledge (e.g., PCK, subject matter), dispositions (motivation, interest) should have been integrated into *teacher competence* system which is not the focus of this study. Moreover, this study will further introduce multidimensional item-response-theory (MIRT) to model several latent traits simultaneously and thus provide a promising approach to science teacher competence assessments.

Science teachers play a key role in successfully implementing science education reforms and providing all students with meaningful science learning opportunities. The construction of science teachers' core teaching competencies is the key step to promote the development of students' key competences. In order to ensure the content validity of the constructed competency indicators, this study constructed a community of experts, but this still cannot avoid a one-sided understanding of the core competencies of science teachers. Since researchers lack the experience of the real environment of professional learning and training during teachers' development and teaching practice, the description of individual characteristics of science teachers, such as their professional experience and competencies, are more based on literature research. In addition, due to the lack of professional standards and specialized documents for science teachers in China, many of the contents in this study draw more on science teacher competency documents published by countries /organizations such as the United States, Australia, and the European Union. Therefore, this research calls for the publication of the Chinese version of professional standards for science teachers as soon as possible to guide the professional development of science teachers.

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Declaration of Interest

Authors declare no competing interest.

References

Alake-Tuenter, E., Biemans, H. J. A., Tobi, H., Wals, A. E. J., & Mulder, M. (2012). Inquiry-based science education competencies of primary school teachers: A literature study and critical review of the American National Science Education Standards. *International Journal of Science Education, 34*(17), 2609-2640. https://doi.org/10.1080/09500693.2012.669076

AlakeTuenter, E., Biemans, H. J. A., Tobi, H., & Mulder, M. (2013). Inquiry-based science teaching competence of primary school teachers: A Delphi study. *Teaching & Teacher Education, 35*, 13-24. https://doi.org/10.1016/j.tate.2013.04.013

Alt, D. (2018). Science teachers' conceptions of teaching and learning, ICT efficacy, ICT professional development and ICT practices enacted in their classrooms. *Teaching & Teacher Education, 73,* 141-150. https://doi.org/10.1016/j.tate.2018.03.020

Australian Science Teachers Association and Teaching Australia. (2002). *National professional standards for highly accomplished teachers of science*. Australian Science Teachers Association.

Aydeniz, M., & Dogan, A. (2016). Exploring pre-service science teachers' pedagogical capacity for formative assessment through analyses of student answers. *Research in Science & Technological Education, 34*(2), 125-141. https://doi.org/10.1080/02635143.2015.1092954

Bawane, J., & Spector, J. M. (2009). Prioritization of online instructor roles: Implications for competency-based teacher education programs. *Distance Education*, *30*(3), 383-397. https://doi.org/10.1080/01587910903236536

Beasley, W. (1982). Student teaching: Perceived confidence at attaining teaching competencies during preservice courses. *European Journal of Science Education, 4*(4), 421-427. https://doi.org/10.1080/0140528820040408

Bell, B., & Cowie, B. (2001). The characteristics of formative assessment in science education. *Science Education, 85*(5), 536–553. https://doi.org/10.1002/sce.1022

Beyer, C. J., & Davis, E. A. (2012). Developing preservice elementary teachers' pedagogical design capacity for reform-based curriculum design. *Curriculum Inquiry, 42*(3), 386-413. https://doi.org/10.1111/j.1467-873x.2012.00599.x

Bieri, C., & Schuler, P. (2011). Cross-curricular competencies of student teachers: A selection model based on assessment centre admission tests and study success after the first year of teacher training. *Assessment & Evaluation in Higher Education*, *36*(4), 399-415. https://doi.org/10.1080/02602938.2011.557146

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Blömeke, S., Gustafsson, J.-E., & Shavelson, R. J. (2015). Beyond dichotomies. competence viewed as a continuum. *Zeitschrift für Psychologie, 223*(1), 3–13. https://doi.org/10.1027/2151-2604/a000194

Bruce G. Waldrip, & Leonie J. Rennie. (2006). The effective science teacher: Perceptions of teachers and their principals. *Asia-Pacific Journal of Teacher Education, 20*(1), 13-24. https://doi.org/10.1080/0311213920200103

Butzow, J. W., & Qureshi, Z. (1978). Science teachers' competencies: A practical approach. Sci*ence Education, 62*(1), 59-66. https://doi.org/10.1002/sce.3730620109

Bybee, R. W. (1995). Achieving scientific literacy. *The Science Teacher*, *62*(7), 28.

Caena, F. (2014). Teacher Competence Frameworks in Europe: Policy-as-Discourse and Policy-as-Practice. *European Journal of Education*, *49*(3), 311-331. https://doi.org/10.1111/ejed.12088

Carlson, J., & Daehler, K. R. (2019). The refined consensus model of pedagogical content knowledge in science education. In A. Hume, R. Cooper, & A. Borowski (Eds.), *Repositioning pedagogical content knowledge in teachers' knowledge for teaching science* (pp. 77–92). Springer Singapore. https://doi.org/10.1007/978-981-13-5898-2_2

Carril, P. C. M., Sanmamed, M. G., & Sellés, N. H. (2013). Pedagogical roles and competencies of university teachers practicing in the e-learning environment. *The International Review of Research in Open and Distributed Learning, 14*(3), 462-487. https://doi.org/10.19173/irrodl.v14i3.1477

Castle, K. (2006). Autonomy through pedagogical research. *Teaching & Teacher Education, 22*(8), 1094-1103. https://doi.org/10.1016/j.tate.2006.07.001

Champagne, A. B., & Hornig, L. E. (1987). Issues of science teacher quality, supply, and demand. *Science Education*, *71*(1), 57-76. https://doi.org/10.1002/sce.3730710110

Chang, P. T., Huang, L. C., & Lin, H. J. (2000). The fuzzy Delphi method via fuzzy statistics and membership function fitting and an application to the human resources. *Fuzzy Sets & Systems, 112*(3), 511-520. https://doi.org/10.1016/S0165-0114(98)00067-0

Cheng, E. C. (2014). Learning study: nurturing the instructional design and teaching competency of pre-service teachers. *Asia-Pacific Journal of Teacher Education, 42*(1), 51-66. https://doi.org/10.1080/1359866X.2013.869546

Chin, C. (2006). Classroom interaction in science: Teacher questioning and feedback to students' responses. *International Journal of Science Education, 28*(11), 1315-1346. https://doi.org/10.1080/09500690600621100

Dalkey, N., & Helmer, O. (1963). An experimental application of the Delphi: Method to the use of experts. *Management Science, 9*, 458-467. https://doi.org/10.1287/mnsc.9.3.458

Davis, E. A., Beyer, C., Forbes, C. T., & Stevens, S. (2011). Understanding pedagogical design capacity through teachers' narratives. *Teaching & Teacher Education, 27*(4), 797-810. https://doi.org/10.1016/j.tate.2011.01.005

Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. *Review of Educational Research*, *76*(4), 607-651. https://doi.org/10.3102/00346543076004607

Deacon, C., Hajek, A., & Schulz, H. (2017). Graduate teaching assistants' perceptions of teaching competencies required for work in undergraduate science labs. *International Journal of Science Education*, *39*(16), 2189-2208. https://doi.org/10.1080/09500693.2017.1367110

Deng, F., Chai, C. S., Tsai, C., & Lee, M. (2014). The relationships among Chinese practicing teachers' epistemic beliefs, Pedagogical Beliefs and Their Beliefs about the Use of ICT. *Educational Technology & Society*, *17*(2), 245-256. https://doi.org/10.1080/09500693.2017.1367110

Deveci, I. (2016). Perceptions and competence of Turkish pre-service science teachers with regard to entrepreneurship. *Australian Journal of Teacher Education, 41*(5), 153-170. https://doi.org/10.14221/ajte.2016v41n5.10

De Putter-Smits, L. G. A., Taconis, R., Jochems, W., & Van Driel, J. (2012). An analysis of teaching competence in science teachers involved in the design of context-based curriculum materials. *International Journal of Science Education, 34*(5), 701-721. https://doi.org/10.1080/09500693.2012.656291

Distler, J. W. (2007). Critical thinking and clinical competence: Results of the implementation of student-centered teaching strategies in an advanced practice nurse curriculum. *Nurse Education in Practice, 7*(1), 53-59. https://doi.org/10.1016/j.nepr.2006.08.003

Dobber, M., Akkerman, S. F., Verloop, N., & Vermunt, J. D. (2012). Student teachers' collaborative research: Small-scale research projects during teacher education. *Teaching & Teacher Education, 28*(4), 609-617. https://doi.org/10.1016/j.tate.2012.01.009

Eichinger, J. (1992). College science majors' perceptions of secondary school science: An exploratory investigation. *Journal of Research in Science Teaching, 29*(6), 601-610. https://doi.org/10.1002/tea.3660290608

Flores, J. G. (2016). Variables associated to the self-efficacy perceived by Spanish secondary school science
teachers. *Revista de Educacion,* (373), 85-108. https://doi.org/10.4438/1988-592X-RE-2016-373-322

Forbes, C. T., & Davis, E. A. (2010). Curriculum design for inquiry: Preservice elementary teachers' mobilization and adaptation of science curriculum materials. *Journal of Research in Science Teaching, 47*(7), 820-839. https://doi.org/10.1002/tea.20379

Gilberts, G. H., & Lignugariskraft, B. (1997). Classroom management and instruction competencies for preparing elementary and special education teachers. *Teaching & Teacher Education, 13*(6), 597-610. https://doi.org/10.1016/S0742-051X(97)80003-0

Green, R. D., & Osah-Ogulu, D. J. (2003). Integrated science teachers' instructional competencies: An empirical survey in rivers state of Nigeria. *Journal of Education for Teaching: International Research and Pedagogy, 29*(2), 149-158. https://doi.org/10.1080/0260747032000092657

Guiller, J., Durndell, A., & Ross, A. (2008). Peer interaction and critical thinking: Face-to-face or online discussion?. *Learning and Instruction, 18*(2), 187-200. https://doi.org/10.1016/j.learninstruc.2007.03.001

Hensiek, S., Dekorver, B. K., Harwood, C. J., Fish, J., O'Shea, Kevin, & Towns, M. (2016). Improving and assessing student hands-on laboratory skills through digital badging. *Journal of Chemical Education*, *93*(11), 1846-1854. https://doi.org/10.1021/acs.jchemed.6b00234

Hofstein, A., Eilks, I., & Bybee, R. (2011). Societal issues and their importance for contemporary science education—a pedagogical justification and the state-of-the-art in Israel, Germany, and the USA. *International Journal of Science and Mathematics Education*, *9*(6), 1459-1483. https://doi.org/10.1007/s10763-010-9273-9

Ingersoll, R. M. (2011). Do we produce enough mathematics and science teachers? *Phi Delta Kappan*, *92*(6), 37-41. https://doi.org/10.1177/003172171109200608

Ishikawa, A., Amagasa, M., Shiga, T., Tomizawa, G., Tatsuta, R., & Mieno, H. (1993). The max-min Delphi method and fuzzy Delphi method via fuzzy integration. *Fuzzy Sets and Systems, 55*(3), 241-253. https://doi.org/10.1016/0165-0114(93)90251-C

Jang, S. (2014). The effect of students' communication ability, leadership, critical thinking ability, and ICT-literacy on the learner's reflective thinking in the project-based learning environment. *The Korean Journal of Educational Methodology Studies, 26*(3), 391-407. https://doi.org/10.17135/jdhs.2019.19.1.31

John, P. D. (2006). Lesson planning and the student teacher: Re-thinking the dominant model. *Curriculum Studies, 38*(4), 483-498. https://doi.org/10.1080/00220270500363620

Kadioglu-Akbulut, C., Cetin-Dindar, A., Küçük, S., & Acar-Sesen, B. (2020). Development and Validation of the ICT-TPACK-Science Scale. *Journal of Science Education and Technology*, *29*(3), 355-368. https://doi.org/10.1007/s10956-020-09821-z

Kaendler, C., Wiedmann, M., Rummel, N., & Spada, H. (2015). Teacher competencies for the implementation of collaborative learning in the classroom: A framework and research review. *Educational Psychology Review, 27*(3), 505-536. https://doi.org/10.1007/s10648-014-9288-9

Kaufmann, A., & Gupta, M. M. (1988). *Fuzzy mathematical models in engineering and management science*. Elsevier Science.

Klein, J. D., & Jun, S. (2014). Skills for instructional design professionals. *Performance Improvement, 53* (2), 41-46. https://doi.org/10.1002/pfi.21397

Knightbardsley, A., & Mcneill, K. L. (2016). Teachers' pedagogical design capacity for scientific argumentation. *Science Education, 100*(4), 645-672. https://doi.org/10.1002/sce.21222

Li, A. T., & Lin, J. W. (2014). Constructing core competency indicators for clinical teachers in Taiwan: A qualitative analysis and an analytic hierarchy process. *BMC Medical Education*, *14*(1), 75. https://doi.org/10.1186/1472-6920-14-75

Lin, L.-Z., & Lu, C.-F. (2013). Fuzzy group decision-making in the measurement of ecotourism sustainability potential. *Group Decision and Negotiation, 22*(6), 1051–1079. https://doi.org/10.1007/s10726- 012-9305-7

Lopezperez, M. V., Perezlopez, M. C., & Rodriguezariza, L. (2011). Blended learning in higher education: Students' perceptions and their relation to outcomes. *Computers & Education, 56*(3), 818-826. https://doi.org/10.1016/j.compedu.2010.10.023

McClelland, D., C. (1973). Testing for competence rather than for "intelligence". *American Psychologist, 28*(1), 1-14. https://doi.org/10.1037/h0034092

Moynihan, S., Paakkari, L., Valimaa, R., Jourdan, D., & Mannixmcnamara, P. (2015). Teacher competencies in health education: Results of a Delphi study. *PLOS ONE*, *10*(12), 1-17. https://doi.org/10.1371/journal.pone.0143703

Mulder, M. (2012). European vocational education and training. In Wilson, J. P. (eds.). *Human resource development: Learning, education, and training* (pp. 155-175). Kogan Page.

Murray, T. J., Pipino, L. L., & van Gigch, J. P. (1985). A pilot study of fuzzy set modification of Delphi. *Human Systems Management*, *5* (1), 76-80. https://doi.org/10.1080/0886571X.2011.550171

National Research Council. (1996). *National science education standards*. Washington DC, National Academy Press.

OECD. (2005). *The definition and selection of key competencies: Executive summary*. http://www.deseco.admin.ch/2005.dskcexecutivesummary.pdf

OECD. (2006). *Assessing scientific, reading and mathematical literacy: A framework for PISA 20*06. Paris: OECD PUBLICATIONS.

Pacific Policy Research Center. (2010). *21st Century Skills for Students and Teachers*. United States: Honolulu: Kamehameha Schools, Research & Evaluation Division.

Park, S., & Oliver, J. S. (2008). Revisiting the conceptualisation of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education, 38*(3), 261-284. https://doi.org/10.1007/s11165-007-9049-6

Saaty, T. L. (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*, *15*(3), 234-281. https://doi.org/10.1016/0022-2496(77)90033-5

Saido, G. A. M., Siraj, S., Dewitt, D., & Al-Amedy, O. S. (2018). Development of an instructional model for higher order thinking in science among secondary school students: A fuzzy Delphi approach. *International Journal of Science Education*, *40*(8), 847-866. https://doi.org/10.1080/09500693.2018.1452307

Sedibe, M., Maema, E., Fourie, J., & Peter, K. (2014). Natural science teachers' perceptions of their teaching competence in senior phase township schools in Soweto Area, Gauteng Province. *Journal of Anthropology, 18*(3), 1115-1122. https://doi.org/10.1080/09720073.2014.11891594

Shaharabani, Y. F., & Tal, T. (2017). Teachers' practice a decade after an extensive professional development program in science education. *Research in Science Education, 47*(5), 1031-1053. https://doi.org/10.1007/s11165-016-9539-5

Simpson, R. D., & Brown, D. R. (1977). Validating science teaching competencies using the Delphi method. *Science Education*, *61*(2), 209-219. https://doi.org/10.1002/sce.3730610212

Spencer, L. M., & Spencer, S. M. (1993). *Competence at work model for superior performance*. Wiley.

Spore, L. (1962). The competences of secondary school science teachers. *Science Education*, *46*(4), 319-334. https://doi.org/10.1002/sce.3730460410

Stenhouse, L. (1981). What counts as research? *British Journal of Educational Studies*, *29*(2), 103-114. https://doi.org/10.2307/3120018

Sudirman, S. (2017). Efforts to improve teacher competence in developing a lesson plan through sustainable guidance in SMKN 1 Mamuju. *Journal of Education & Practice, 8*(5), 114-119.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Tiana, A., Moya, J., & Luengo, F. (2011). Implementing key competences in basic education: Reflections on curriculum design and development in Spain. *European Journal of Education, 46*(3), 307-322. https://doi.org/10.1111/j.1465-3435.2011.01482.x

Tigelaar, D. E. H., Dolmans, D. H. J. M., Wolfhagen, I. H. A. P., & van der Vleuten, C. P. M. (2004). The development and validation of a framework for teaching competencies in higher education. *Higher Education: The International Journal of Higher Education and Educational Planning, 48*(2), 253–268. https://doi.org/10.1023/B:HIGH.0000034318.74275.e4

Tulloch, B. R. (1986). A factor analytic study of secondary science teacher competencies within which growth is perceived as important by science teachers, supervisors, and teacher educators. *Journal of Research in Science Teaching*, *23*(6), 543-556. https://doi.org/10.1016/j.chb.2017.03.010

UNESCO. (2011). UNESCO ICT Competency Framework for Teachers. UNESCO, Paris. http://unesdoc.unesco.org/images/0021/002134/213475e.pdf

Van Laar, E., Van Deursen, A. J. A. M., Van Dijk, J. A. G. M., & De Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. *Computers in Human Behavior, 72*(7), 577-588. https://doi.org/10.1016/j.chb.2017.03.010

Veal, W. R., & MaKinster, J. G. (1999). Pedagogical content knowledge taxonomies [Electronic version]. *Electronic Journal of Science Education, 3*(4). http://unr.edu/homepage/crowther/ejse/ejsev3n4.html

Wan, Y., & Bi, H. (2019). What major "socio-scientific topics" should the science curriculum focused on? A Delphi study of the expert community in China. *International Journal of Science and Mathematics Education*, *18*(1), 67-77. https://doi.org/10.1007/s10763-018-09947-y

Weinert, F. E. (2001). Concept of competence. A conceptual clarification. In D. S. Rychen & L. H. Salganik (Hrsg.), *Defining and selecting key competencies* (S. 45–65). Hogrefe & Huber.

Willegems, V., Consuegra, E., Struyven, K., & Engels, N. (2017). Teachers and pre-service teachers as partners in collaborative teacher research: A systematic literature review. *Teaching & Teacher Education*, *64*, 230-245. https://doi.org/10.1016/j.tate.2017.02.014

Wu, L. C., Chao, L. L., Cheng, P. Y., Tuan, H. L., & Guo, C. J. (2018). Elementary teachers' perceptions of their professional teaching competencies: Differences between teachers of math/science majors and non-math/science majors in Taiwan. *International Journal of Science and Mathematics Education*, *16*(5), 877-890. https://doi.org/10.1007/s10763-017-9821-7

Wuttke, E., & Seifried, J. (2017). Modeling and measurement of teacher competence: Old wine in new skins?. In Mulder, M. (eds.). *Competence-based vocational and professional education* (pp. 883-901). Springer, Cham.

Yao, J., & Guo, Y. (2018). Core competences and scientific literacy: The recent reform of the school science curriculum in China. *International Journal of Science Education, 40*(15), 1913-1933. https://doi.org/10.1080/09500693.2018.1514544

Ye, J., Chen, D., & Kong, L. (2019). Bibliometric analysis of the WOS literature on research of science teacher from 2000 to 2017. Journal of Baltic Science Education, 18(5), 732-747. https://doi.org/10.33225/jbse/19.18.732

Zhang, R., Liu, X., Yang, Y., Jennifer, T., & Boyu, S. (2017). Preservice science teachers' instructional design competence: Characteristics and correlations. *Eurasia Journal of Mathematics, Science and Technology Education, 14*(3), 1075-1096. https://doi.org/10.12973/ejmste/81553

Zhu, C., & Wang, D. (2014). Key competencies and characteristics for innovative teaching among secondary school teachers: A mixed-methods research. *Asia Pacific Education Review, 15*(2), 299-311. https://doi.org/10.1007/s12564-014-9329-6

Zhu, C., Wang, D., Cai, Y., & Engels, N. (2013). What core competencies are related to teachers' innovative teaching? *Asia-Pacific Journal of Teacher Education, 41*(1), 9-27. https://doi.org/10.1080/1359866X.2012.753984

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CONCEPTIONS OF LEARNING SCIENCE IN INFORMAL ENVIRONMENTS AMONG PRIMARY SCHOOL STUDENTS IN MAINLAND CHINA

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Abstract. *Previous studies on students' conceptions of learning science (COLS) have focused primarily on formal environments. In these studies, students' COLS were positively associated with their approaches to and outcomes for science learning. However, little research has been conducted to explore students' conceptions of learning science in informal environments (COLSIE), despite its importance to students' academic achievement. To fill this research gap, this study qualitatively and quantitatively explored Chinese primary school students' COLSIE. First, in Study I, interview data gathered from a group of 80 students were analysed using the phenomenographic method, and ten hierarchical categories of COLSIE emerged (e.g., communicating and explaining). Based on these categories, a survey was developed and distributed to another group of 414 students in Study II. Exploratory factor analysis was conducted to validate the survey, which revealed nine factors matching the ten categories except for the initial categories of applying and understanding. This study also revealed the commonalities and uniqueness of COLSIE in comparison with students' COLS in formal environments. The findings suggested that informal science learning experiences may strengthen students' impressions of science practices. Science educators are encouraged to provide their students with opportunities to engage with science practices in informal environments.*

Keywords: *primary school students; Mainland China; conceptions of learning science; informal environments; phenomenographic*

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Introduction

Science learning is a process occurring in both formal and informal environments (Bell et al., 2009; Duschl et al., 2007). Students' experiences of learning science in informal environments include a broad array of activities, such as visiting museums and natural parks, attending science clubs and out-of-school programs, reading science books, and searching for science-related information online (Aubusson et al., 2012; Bell et al., 2009; Lin & Schunn, 2016). These diversified learning experiences have been found to be different from those in formal environments in various aspects (Bell et al., 2009; Falk, 2005; Tal, 2012). Accordingly, students' conceptions of learning science in informal environments (COLSIE) may be different from their conceptions of learning science (COLS) in formal environments, as conceptions of learning have been found to be domain-specific and context-dependent (e.g., Marton et al., 1993; Tsai, 2004).

Previous studies on students' COLS have focused primarily on students in formal learning situations and found that students' COLS were positively associated with their approaches to and outcomes for science learning (e.g., Zheng et al., 2018). However, little research has been conducted to explore students' COLSIE, given the importance of learning science in informal environments to students' academic achievement worldwide (Bell et al., 2009; Shaby & Vedder-Weiss, 2019; Tang & Zhang, 2020). To fill this research gap, this study explored primary school students' COLSIE in Mainland China.

Learning Science in Informal Environments

Students learn science in either formal or informal environments. While formal science learning normally takes place at school and in the classroom, informal environments for learning science include various out-of-school con-

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texts such as museums, science centres, and summer programs (e.g., Bell et al., 2009). Learning science in informal environments is also known as outdoor education, everyday science learning, lifelong learning, and free-choice learning (Ellenbogen, 2003; Falk, 2005; Philip & Azevedo, 2017; Tal, 2012; Vedder-Weiss & Fortus, 2011; Zimmerman et al., 2019). In this study, the term informal science learning is adopted and defined as learning science in organized situations (e.g., participating in science clubs), in everyday life (e.g., reading sciences books), and through the media or web (e.g., watching science-related TV programs and searching for science-related information by using media) (Aubusson et al., 2012; Bell et al., 2009; Lin & Schunn, 2016; Tang & Zhang, 2020). According to the National Research Council, informal science learning is guided by "learner interests, voluntary, personal, ongoing, contextually relevant, collaborative, nonlinear, and open-ended" (Bell et al., 2009, p. 11).

It has been widely recognized that the characteristics of students' experiences of learning science in informal environments are different from those in formal environments. First, informal science learning includes a broad array of activities occurring across various environments, including designed, every-day, or public settings (Anderson & Ellenbogen, 2012; Aubusson et al., 2012; Bell et al., 2009; Lin & Schunn, 2016). Second, with respect to the structure of learning activities, informal science learning seems structureless and nonsequential. However, it provides students with more opportunities to communicate and interact with peers or other adults (Bell et al., 2009). Finally, informal science learning experiences are often believed to be driven by learners' intrinsic motivations and interests (Alexander et al., 2012; Holmes, 2011). That is, learners tend to voluntarily participate in informal science learning activities (Falk, 2005; Tal, 2012).

Recent studies have tried to classify students' informal science learning experiences into finer grain-sized dimensions. For example, according to the object of learning and structure of activity, they were specified into three areas: everyday settings and family activities, designed environments, and after-school and adult programs (Bell et al., 2009). In addition, Lin and Schunn (2016) pointed out that students' informal science learning experiences can be considered from four dimensions, i.e., informal home science, semiformal science, nature, and museum.

Conceptions of Learning Science

Conceptions of learning refer to "a coherent system of knowledge and belief about learning and related phenomena" (Negovan et al., 2015, p. 643). In the science education field, students' COLS were found to be correlated with their science learning process (Chiou et al., 2012; Lee et al., 2008). Lee et al. (2008) reported that high school students who possessed higher-level or constructivist COLS were more likely to adopt deep approaches to learning science. Researchers have also established a close link between students' COLS and self-efficacy in learning science, i.e., an essential factor in predicting their science learning achievement performance (Lee et al., 2019; Tsai et al., 2011). For instance, Tsai et al. (2011) revealed that high school students' higher-level COLS positively predicted their self-efficacy in learning science. In a recent study, Zheng et al. (2018) investigated the interrelationships among students' COLS, their approaches to and the self-efficacy of learning science. They reported that primary school students' higher-level COLS had a positive influence on deep approaches to learning science, and only students' deep approaches to learning science had a positive impact on their self-efficacy of learning science.

The phenomenographic method is often adopted to explore students' conceptions of learning in various topics (Marton et al., 1993; Tsai, 2004; Zhao & Thomas, 2016). The phenomenography was considered "a distinctive qualitative approach" to exploring students' learning (Richardson, 1999, p. 53). It has been utilized by many researchers in Sweden, Australia, Hong Kong, and Taiwan (Chiu et al., 2016; Gao & Watkins, 2002; Saljo, 1979; Tsai, 2004). The phenomenography aimed at describing, analysing, and understanding learning experiences (Marton, 1981) and believed that there are variations in how different people conceive of learning experiences (Marton & Booth, 1997). Variations can be discovered by combining interviews, protocols, and discourse analysis (Richardson, 1999). Within this framework, an outcome space would be established to represent the variations in students' qualitatively different, hierarchically related conceptions of learning (Marton & Booth, 1997; Tsai, 2004). Marton and Booth (1997) defined a hierarchical outcome space, as each successive category is a more complex way of experiencing learning. For example, in a pioneering phenomenographic work, Saljo (1979) revealed five qualitatively different and increasingly comprehensive categories of conceptions of learning:, i.e., (i) *increase of knowledge*, (ii) *memorizing*, (iii) *acquisitions of facts and procedures that can be retained and/or utilized in practice*, (iv) *abstraction of meaning*, and (v) *an interpretative process aimed at the understanding of reality*.

Overall, previous studies have shown that students' conceptions of learning are influenced by various do-

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main-specific and context-dependent factors, e.g., subjects, culture, and educational environments (Boulton-Lewis et al., 2000; Chiu et al., 2016; Marton et al., 1993; Tsai, 2004). First, for instance, students' COLS may be different from learning other subjects. In one of the early studies that applied phenomenographic methods, Tsai (2004) explored Taiwanese high school students' COLS. His study revealed seven increasingly sophisticated categories of COLS: *memorizing*, *testing*, *calculating and practising tutorial problems*, *increasing knowledge*, *applying*, *understanding*, and *seeing in a new way*. Specifically, the origin of the conception of *calculating and practising tutorial problems* was suggested to be related to the nature of school science. That is, science was always presented as a series of numbers, formulas, calculations, and tutorial problem solving in school science texts and tests.

Students' COLS may also be influenced by culture. Initially, it was assumed that there might be some unique conceptions of learning or learning sciences that are "endemic" to a specific culture (Dahlin & Regmi, 1997; Negovan et al., 2015). Previous studies have verified this assumption to some extent (e.g., Marton et al., 1993; Tsai, 2004). For instance, *testing*, a new category of COLS revealed by Tsai (2004), was attributed to Taiwan's prevailing culture of examinations. In a similar vein, Zhao and Thomas (2016) found a new category of COLS, i.e., *listening to their teacher*, among high school students in Mainland China. This category was believed to represent the feature of obedience stressed and reinforced in high schools in Mainland China.

In addition, another series of studies has shown that students' different educational environments could influence their COLS. For example, Tsai and Kuo (2008) explored students' COLS in a cram school, a unique educational context that aims to improve students' exam scores through the repeated practise of tutorial exercises. Their study found that most student participants conceptualized learning science as memorizing school knowledge, preparing for tests, or calculating and practising tutorial problems. In a recent study, Chiu, Lin, and Tsai (2016) adopted the phenomenographic method to investigate Taiwanese university science-major students' COLS in the laboratory and identified six hierarchical categories: *memorizing*, *acquiring manipulative skills*, *obtaining authentic experience*, *examining prior knowledge*, *reviewing prior learning profiles*, and *achieving in-depth understanding*. While the conceptions of *memorizing* and *achieving in-depth understanding* have been previously identified by Tsai (2004) for COLS in general, the remaining four conceptions are unique for COLS in the laboratory.

Boulton-Lewis et al. (2000) expanded their focus to informal environments. They compared students' conceptions of formal and informal learning among 22 Aboriginal and Torres Strait Islander students from three Australian universities. Their study revealed clear differences between students' conceptions of learning in different environments. Specifically, three main conceptions were evident for formal learning, i.e., *acquiring knowledge*, *understanding*, and *personal growth*. In comparison, four conceptions were confirmed for informal learning, i.e., *acquiring skills by observation and imitation*, *acquiring cultural and social knowledge* from family members or elderly individuals, *developing practical skills* by active problem solving, and *seeking information* by finding appropriate resources. Importantly, most students in their study showed inconsistency between their conceptions of formal learning and those of informal learning.

Research Questions

Previous studies have demonstrated that students' conceptions of learning are often affected by different learning environments and their cultural values (Chiu et al., 2016; Tsai, 2004; Zhao & Thomas, 2016). Overall, the apparent differences between students' conceptions of formal and informal learning in general have also been partially evidenced by previous studies (Boulton-Lewis et al., 2000). While COLS have been widely studied in formal environments, little research has been conducted regarding this topic in informal environments. Thus, it is important to explore students' COLS exclusively in informal environments.

The current research aimed to explore primary school students' COLSIE in Mainland China. It consisted of two studies: in Study I, phenomenographic analysis was conducted on students' interview data to qualitatively explore their COLSIE; in Study II, based on the qualitatively different categories of COLSIE obtained in Study I, a COLSIE survey was developed and distributed to a group of primary school students. Later, its reliability and validity were quantitatively assessed. Specifically, this research was conducted to address the following research questions:

1. What are the different categories of descriptions that classify COLSIE held by primary school students in Mainland China?
2. To what extent is the COLSIE survey reliable and valid for assessing primary school students' COLSIE in Mainland China?

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Research Methodology

General Background

In the current study, student participants aged 10 to 12 years were recruited from grades 4 to 6 in seven primary schools in South China. These schools were selected through purposive sampling. Specifically, they varied in terms of students' enrolment, the quality of teachers, the socioeconomic status of students' families, and the socioeconomic level of the local communities. Therefore, the student participants in the study were believed to be representative of the majority of primary school students in Mainland China due to the diverse background information of these schools. It also met the requirements of the participant's variation suggested by the phenomenographic method.

Study I: Qualitative Exploration and Categorization of COLSIE

Participants and Procedures

In Study I, 80 students (41 boys and 39 girls) from three of the seven primary schools voluntarily participated in an individual interview. Prior to the interview, these students were confirmed to have informal science learning experiences. They were interviewed individually in a semistructured way. The individual student interviews were conducted in Chinese. Two researchers majoring in science education conducted the interviews.

Modified from two previous studies on COLS (Chiu et al., 2016; Tsai, 2004), five interview questions were used:

- What do you usually do when learning science in informal environments?
- How do you understand the meaning of learning science in informal environments? Or, in your opinion, what does learning science in informal environments mean to you?
- How do you learn science in informal environments?
- How do you know that you have learned something about science in an informal environment?
- What do you think the purpose of learning science in informal environments is?

Data Analysis

The individual student interviews were electronically recorded. These recorded interviews were transcribed into verbatim transcripts. Two researchers jointly analysed these transcripts following the phenomenographic method (Chiu et al., 2016; Tsai, 2004). First, for each student's transcript data, the most important sentences or keywords were marked to characterize the student's views of learning science in informal environments. Then, by comparing these highlighted sentences and keywords, the similarities and differences across students' responses were carefully investigated and identified. Finally, a hierarchical system composed of qualitatively different conceptions of description was constructed, which provided a framework to classify the student participants' COLSIE.

To illustrate the data analytical procedure in detail, two students' interview data are shown below. Each student was given a numerical identification with three digits, in which the first digit indicates his/her grade level (4, 5, or 6), and the remaining two digits were a sequential identifying number randomly assigned to each student in the same grade group. For example, 429 referred to a fourth-grade student who was also the 29th participant in grade 4. When collecting data from each student, we stored each student's information in one file using his or her three-digit identification number. For example, student 429 had a file named 429, and all his/her answers to the interviews would be recorded there. The interview data presented in the following section were translated from Chinese to English by the authors. An additional bilingual researcher unfamiliar with the current research was asked to translate the English version of the interview data back to Chinese to ensure translation correctness. The back-translated data were then compared against the original data for further revision and refinement. No misinterpretations were detected, and hence, the translation process was finalised.

429. Learning science in informal environments is about real experiences. For example, I once *<u>came into contact</u>* with some snails on the grass and *<u>observed</u>* them carefully. I have also *<u>watched</u>* the process of larval metamorphosis into a chrysalis.

517. I *<u>witnessed</u>* some specimens of microorganisms in a museum. With my mom's assistance, I also performed some

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> experiments on oral epithelial cells and shrimp eggs. (A follow-up question was asked: How do you know that you have learned something about science in an informal environment?) I got to see exactly what the microorganisms and onion samples look like.

In the first part of the interview segment, some keywords indicating the student's views of learning science in informal environments were marked, e.g., "came into contact," "observed," and "watched". In a similar manner, another set of keywords was highlighted in the second example, such as "witnessed" and "see exactly." Next, by looking across these two students' responses, a category of *obtaining authentic experience through activities* emerged to capture the similarity of the keywords mentioned by the two students above. Overall, a total of ten categories in a hierarchical order were identified to represent students' COLSIE, which will be discussed in the results section. These qualitatively different categories presented here could serve as a coding scheme to categorize students' COLSIE.

Previous studies have also revealed that students' conceptions of learning may be across multiple categories (e.g., Lin & Tsai, 2008; Tsai, 2009). Following recent developments, this study used the "main" conceptions proposed in Tsai (2009) to provide a certain representation of the students' major views of COLSIE. Specifically, the main conception referred to the most frequent conception each student expressed in the interview. For example, in the results section, two quotations from student 601 were identified as *applying* and *understanding*. However, in his complete interview data, the conception of *applying* was mentioned only once, whereas the conception of *understanding* was discussed three times. Hence, student 601's main conception was identified as *understanding*. In a similar manner, two researchers classified each student's main conception into one of the ten categories. For students who had two or more conceptions that shared the same highest frequency, the researchers examined their interview transcripts again, discussed case by case, and then determined a final main conception.

Study II: Development and Validation of the COLSIE Survey

Instrument

In line with studies on students' conceptions of learning, some researchers have argued the importance of developing a corresponding instrument to conduct a large-scale investigation, which would provide empirical evidence for the validity of the structure of conceptions of learning derived from interview data (Chiu et al., 2016; Lee et al., 2008; Lin & Tsai, 2013). Therefore, a COLSIE survey was developed in Study II to validate the ten categories of COLSIE identified in Study I.

The ten categories of students' COLSIE identified in Study I served as the guiding framework for the development of the COLSIE survey (see the Appendix). For each of the ten categories, statements or sentences were extracted from the transcripts to represent each category. Concurrently, some items from Lee, Johansson, and Tsai's (2008) Conceptions of Learning Science Inventory and Chiu, Lin, and Tsai's (2016) Conceptions of Learning Science by Laboratory Survey were also adopted. These items modified from previous studies are marked with an asterisk.

For each of the ten categories, three to six five-point Likert-type items ranging from *strongly agree* to *strongly disagree* were constructed. As a result, a 52-item, ten-factor initial version of the COLSIE survey was developed (see the Appendix). The face validity of the survey was first evaluated by two science teachers and nine of their students. Except for minor wording modifications, both teachers and their students agreed that the instrument was suitable for assessing the target student population.

Participants and Procedures

The COLSIE survey was randomly distributed to a group of 413 students (236 boys and 176 girls) from the remaining four schools recruited for the current study. Specifically, the survey was presented in Chinese and distributed by their teachers in a 45-minute free period, which was sufficient for the students to complete the survey.

Data Analysis

After students' survey responses were collected, exploratory factor analysis (EFA) with principal component extraction and oblimin rotation was conducted to explore the structure of the survey. Principal component extraction was chosen to estimate the number of latent factors extracted from the empirical data, which provided

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evidence for the construct validity of the survey. It may also help validate ten categories of the COLSIE identified in Study I. Specifically, the number of factors was determined based on the criteria of eigenvalues greater than 1. Next, oblimin rotation was used to determine the factor structure because it is reasonable to assume that the factors (or the various categories of students' COLSIE) are correlated with each other, as they characterized different aspects of a single construct, i.e., their COLSIE. Meanwhile, correlations between the factors were also estimated. In addition, Cronbach's alpha was calculated to guarantee the reliability of each factor and the entire survey (see Table 2). According to DeVellis (2016), a Cronbach's alpha coefficient of 0.65–0.70 is "minimally acceptable", a coefficient between 0.70 and 0.80 is "respectable", and a coefficient between 0.80 and 0.90 is "very good". The statistical analysis was conducted using IBM SPSS Statistics version 23.

Research Results

Study I: Categories of Chinese Primary School Students' COLSIE

In Study I, through a phenomenographic analysis of students' interview data, ten quantitively different categories of COLSIE were identified, which showed progressively comprehensive views with a hierarchical outcome space of COLSIE. They are described below in detail, with some student interview comments provided.

Category 1: Learning Science in Informal Environments as Memorizing

In the first category, the memorization of scientific phenomena, concepts, and facts was seen as the main feature of learning science in informal environments. In other words, the major purpose of learning science in informal environments for some students was to memorize as much information as possible for later recall, as evidenced by the following student interviews:

> 419: I memorize it so that I immediately know the answer when I am asked a relevant question related to science.
> 518: I always try to recall what I have learned (about science). If I can repeat them, it means I have mastered them.

Here, students emphasized that memorization was an important tool for learning science in informal environments. This rehearsal or rote memorization helped them establish science knowledge in their long-term memory, which could be extracted if required (e.g., to respond to questions and to recall).

Category 2: Learning Science in Informal Environments as Practising Tutorial Problems

Students whose response fell into this category had experience practising many tutorial problems in informal environments. For instance, some students stated that:

> 415: I always assign myself some science sublet exercises at home to check to what degree that I have understood the science knowledge.
> 608: My teacher at the cram school always assigns homework after class. I have to apply a specific concept or principle (e.g., the reaction force) to solve a problem. I can get knowledge from problem-solving exercises.

As revealed in the above example, the sources of tutorial problems may be different, and they could be provided by the students' parents or their teachers at cram school. Some students even take the initiative to find and solve some problems by themselves. They were willing to or asked to practise many tutorial problems because they wanted to excel in learning school science. They also believed that practising tutorial problems can foster their conceptual understanding.

Category 3: Learning Science in Informal Environments as Recording by Way of Notetaking

In this category, recording what they observed, felt, and learned was considered by some students a notable outcome of learning science in informal environments. This conception is consistent with some scientific practices documented earlier in the history of science, e.g., the records of Millikan's oil drop experiment and Galileo's inclined

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plane experiment. The student participants, for example, commented that:

> 424: After visiting the Science and Technology Museum exhibitions, I wrote down some reflections of the trips when I got home.
> 502: When doing experiments or reading books, I usually take notes of my thoughts or the new knowledge I have learned.
> 615: When learning science outside the classroom, I like to record what I observed. For example, I will draw the details about the plants.

Given these comments, the students stressed the importance of keeping a record of some details and descriptions of the learning process and outcomes. They believed that writing down essential information or their reflections could facilitate their science learning.

It is worth noting that the conceptions of *memorizing* and *recording* emphasize different aspects of learning outcomes. When the students conceptualize COLSIE as *memorizing*, they store some fragmented facts or concepts of science in their brains internally. However, students who consider COLSIE as *recording* tend to use external devices (e.g., a notebook) to help them sort out the information they obtained and to capture all essential details. The students that fell into the category of *recording* may reflect a traditional proverb: "The faintest ink is better than the best memory." In other words, the students in this category value the importance of notetaking.

Category 4: Learning Science in Informal Environments as Increasing Knowledge

Increasing knowledge was also reported as a major feature of learning science in informal environments. Some student participants believed that learning science in informal environments is an effective way to broaden the scope of their existing scientific knowledge. In other words, in their opinion, knowledge acquired from informal learning is an extension of that taught by their science teachers in the classroom. For instance, students pointed out:

> 406: We can learn something that our teachers have not taught through learning in informal environments. In this way, we know more about science.
> 529: I get to know many modern technologies when visiting the museum of science and technology. I can also learn many things through reading science-related books or doing some experiments by myself.
> 620: In addition to learning science at school, I can learn about science and discover science knowledge in my daily life.

Here, these students believed that knowledge learned in informal environments builds on their previous knowledge acquired from formal science classrooms. In some early works, the conception of *increasing knowledge* was classified as reproductive conceptions of learning (Marton et al., 1993; Saljo, 1979). However, some recent empirical studies in science and engineering education have pointed out that the conceptions of *increasing knowledge* should be classified as constructive conceptions of learning. For example, Lin and Tsai (2009) revealed that college students who preferred laboratory inquiry activities and constructive learning environments tended to show more agreement with the conception of *increasing knowledge*. Lin et al. (2012) also provided empirical evidence that the conception of *increasing knowledge* should pertain to constructive conception through confirmatory factor analysis. In informal environments, students' science learning experiences are often driven by their intrinsic motivations and interests (Alexander et al., 2012; Holmes, 2011). As a result, students might favour active accumulation of a certain amount of science knowledge in informal environments, which shapes informal science learning connected with constructive learning. However, the accuracy of knowledge obtained informally may not be guaranteed.

Category 5: Learning Science in Informal Environments as Obtaining Authentic Experience through Activities

Students in this category conceptualized learning science in informal environments as *obtaining authentic experience through activities*. They expected to observe scientific phenomena or items by engaging in real-life experiences, such as directly interacting with plants and animals in the natural environment or visiting science museums. The students, for instance, stated that:

> 429: Learning science in informal environments is about real experiences. For example, I once came into contact with

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some snails on the grass and observed them carefully. I have also watched the process of larval metamorphosis into a chrysalis.
515: I'd like to conduct some experiments mentioned in my textbook or in the lectures, e.g., the buoyancy caused by the buoyant force or the shadow made on a surface when something stands between a light and the surface.
517: I witnessed some specimens of microorganisms in a museum. With my mom's assistance, I also performed some experiments on oral epithelial cells and shrimp eggs. (A follow-up question was asked: How do you know that you have learned something about science in an informal environment?) I got to see exactly what the microorganisms and onion samples look like.

The students in this category claimed that learning science in informal environments allows them to witness something. Some students with this conception may purposefully act out what they previously mentioned in their learning materials (e.g., the textbook mentioned by student 515). However, some other students with this conception may have no presupposed idea about what they are going to learn in informal environments (e.g., the science museum discussed by student 517) and to obtain real-life experience beyond the classroom.

It is worth noting that there is a clear distinction between *recording* and *obtaining authentic experience*. As discussed in the category of *recording*, students may write down their reflections of their authentic experience. To record, they try to capture the exterior details of the objects or phenomena they have observed. In other words, they focus on the learning outcomes or the tangible end product created in the learning process. In comparison, students who consider COLSIE as *obtaining authentic experience* value the process of the activities they participate in informal environments, as well as the mental and emotional experiences provided during the process.

Category 6: Learning Science in Informal Environments as Communicating and Explaining

Students in this category believed that the primary purpose of learning science in informal environments is to engage in a conversation and to share their science-related knowledge with others. To what extent do they fluently talk about this type of knowledge was recognized as a critical indicator for the quality of their scientific understanding. Students responded that:

403: If I can tell what I know about science out loud to someone else, I know I have mastered it.
503: When talking to my parents or classmates, I always share something interesting about science. It also helps me double-check the extent to which I have learned something.
605: As a volunteer, I will first make sure that I understand the exhibits' scientific principles. Then, I can explain the underlying mechanisms and answer follow-up questions from visitors.

The students in this category claimed that informal environments provide them with opportunities to communicate with others or to explain scientific phenomena to others. Through communication and explanation, their understanding of science may be modified and strengthened.

Category 7: Learning Science in Informal Environments as Applying

Students in this category conceptualized learning science in informal environments as applying their established science-related knowledge to solve practical problems. The scope of application of their knowledge may also be extended when they found themselves in similar or dissimilar situations. By doing so, they also tend to create some "scientific inventions," which may be impractical or may already exist. For example, students claimed that:

402: I am interested in informal science learning because I can apply what I learned outside the school to experience new scientific inventions.
521: Visiting the science museum helps me refresh my memory of some science principles that I learned previously. I found it interesting to apply the same principles to conduct a similar experiment using different home materials.
601: I think that learning science in informal environments can expand my knowledge of science, which I can use to solve problems in my real life and thus makes my life easier.

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According to these statements, students in this category emphasized using their own science-related knowledge in informal environments. That is, informal environments provide students with opportunities to apply their knowledge to solve problems in a real situation or to create something they desire.

It is important to discuss the distinctions between this category and two relevant conceptions, i.e., *practising* and *communicating and explaining*. Although both the *practising* and *applying* highlight solving problems, the *practising* is limited to solving familiar and well-structured problems; in contrast, the *applying* is extended to solving unfamiliar and ill-structured problems in the real world. In addition, the *communicating and explaining* and *applying* conceptions are both based on students' previous existing understanding of science. However, notably, *communicating and explaining* emphasizes human interaction, while the conception of *applying* highlights students' interaction with the material world.

Category 8: Learning Science in Informal Environments as Understanding

In this category, learning science in informal environments was viewed as achieving a deep understanding of scientific knowledge. As shown in the following examples, students believe learning science in informal environments facilitates their understanding of scientific phenomena and provides them with new insights into how science-related devices work.

> 417: Using the planetarium as an example, I can observe many scientific phenomena. After listening to the tour guide's information at the planetarium, I get to know the causes of the phenomenon. I can learn how the observation equipment is made.
> 520: Learning science in informal environments allows us to learn the habits of animals in nature and to understand how plants grow or acquire information regarding food chains and food webs.
> 601: When visiting the science museum, I prefer to experience some science-related facilities and figure out how they work.

Here, learning in informal environments helped students understand the development of theories and principles about the natural world (e.g., how plants grow) and engineering design (e.g., observation equipment). In addition to simply knowing what science is, students in this category are eager to explore further and to make sense of some science development. Accordingly, there is a significant difference between this category and the category of *increasing knowledge*: the former highlights students' understanding of science knowledge in depth, whereas the latter focuses on expanding their understanding to build a large pool of information.

Category 9: Learning Science in Informal Environments as Improving Oneself through Opportunities

In this category, students conceptualized learning science in informal environments as a way of improving themselves. Their goal of learning science in informal environments is to make themselves better people. Improving themselves was further regarded as the foundation of serving family and nation in the long term. For example, students stated that:

> 405: Learning science in informal environments is helpful for my family because it provides me with many career opportunities and choices in the future. In this way, I may serve my country better.
> 416: Learning science in informal environments helps increase my intelligence and abilities.
> 508: When I am learning science in informal environments, I will identify and correct some shortcomings in myself.

Students in this category believed that their intellectual abilities could be improved through learning science in informal environments. Therefore, they will become competitive when entering the job market. Later, they will be able to take care of their family and serve their country better. Interestingly, this view reflected a kind of traditional Chinese culture, namely, Jingshi-zhiyong (经世致用), roughly translated to English as learning should contribute to good governance. Under the influence of traditional culture, students want to improve themselves by learning science in informal environments because they care about their family's well-being and are eager to contribute to their country.

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Category 10: Learning Science in Informal Environments as Seeing in a New Way

In the final category, learning science in informal environments was regarded as obtaining a new way of exploring the natural world. For example, students stated:

> 425: After learning science in informal environments, I now think of the natural world more clearly. I can analyse some phenomena from different perspectives.
> 603: We used to do some science experiments in informal environments. These activities taught me how to understand the nature of science better.

Learning science in informal environments provided students with opportunities to change their epistemology of science. In other words, these informal experiences changed how they approach science phenomena and how they are able to further explore the nature of science from different perspectives.

Distribution of Primary School Students' Main COLSIE

As discussed previously, each student's interview responses were classified into one main individual category, which represented the students' major views of COLSIE. In other words, each student's strongest conception, i.e., the most frequent conception expressed in their interview data, was selected to represent their main conceptions. The distribution of these primary school students' main conceptions is shown below in Table 1.

Table 1
Distribution of Students' Main Conceptions of Learning Science in Informal Environments (n=80).

Category	Main conceptions *n* (%)
Memorizing	0
Practising tutorial problems	1 (1.25)
Recording by way of notetaking	2 (2.50)
Increasing knowledge	34 (42.50)
Obtaining authentic experience through activities	35 (43.75)
Communicating and explaining	1 (1.25)
Applying	2 (2.50)
Understanding	3 (3.75)
Improving oneself through opportunities	2 (2.50)
Seeing in a new way	0

Notes: The frequencies of *memorizing* and *seeing in a new way* were 0 because no one took them as their main conceptions. Using student 518 as an example, while a quotation from him was identified as *memorizing* in Category 1, his main conception was identified as *increasing knowledge* because, in his complete interview data, the conception of *increasing knowledge* was discussed the most frequently (three times). In contrast, the conception of *memorizing* was mentioned only once. Similarly, students' main conceptions were classified into the remaining eight categories because the categories of *memorizing* and *seeing in a new way* were discussed at the lowest frequency in their interview data.

As shown in Table 1, among the 80 interviewed students, the major feature of learning science in informal environments was found to be *obtaining authentic experience through activities* category (n=35), followed by *increasing knowledge* (n=34). However, interestingly, the frequencies for the remaining categories of COLSIE were relatively low.

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Study II: Development and Validation of the COLSIE Survey

In Study II, students' responses to the COLSIE survey were analysed using exploratory factor analysis (EFA) with principal component extraction and oblimin rotation methods. Afterwards, Cronbach's alpha was calculated to assess each factor's reliability and the final version of the COLSIE survey, as suggested by the EFA results. In addition, the correlations between the factors were also estimated. The EFA results and the reliability of the COLSIE survey are shown below in Table 2.

Exploratory Factor Analysis and Reliability of the COLSIE Survey

First, sampling adequacy for EFA was examined using Bartlett's test of sphericity and KMO measurements. The results indicated that the samples were appropriate for EFA ($\chi^2(666)=5436.874$ $p<.001$, and KMO=0.928). During the analysis, items with a factor loading of less than 0.4 were subject to elimination (Netemeyer et al., 2003). As a result, a total of 37 items were retained and formed a nine-factor structure, which explained 59.935% of the cumulative variance, as presented in Table 2. The final version of the COLSIE Survey is listed in the Appendix, in which some items were underlined, as they were suggested to be dropped based on the EFA results.

As shown in Table 2, the nine factors retained were labelled in the order of appearance, such as *memorizing* (ME), *practising tutorial problems* (PP), *recording by way of notetaking* (RE), *increasing knowledge* (IK), *obtaining authentic experience through activities* (OA), *communicating and explaining* (CE), *applying and understanding* (AU), *improving oneself through opportunities* (IO), and *seeing in a new way* (SE). Overall, these nine factors were similar to the ten categories of COLSIE identified in the findings of Study I.

The retained items of the seventh factor (AU), in particular, consisted of original items from *applying* and *understanding*. As shown previously in Study 1, the original categories of *applying* and *understanding* were suggested to be adjacent in the hierarchical outcome space of COLSIE. Accordingly, it seemed reasonable to group both the *applying* category and *understanding* category into a single factor entitled "*applying and understanding*" (AU). Previously, these two categories were grouped into a single factor in studying university students' conceptions of learning chemistry (Li et al., 2013). For instance, students may link the two items derived from the *applying* category, labelled AU1 and AU2 in the Appendix, to *understanding* items. It is possible that applying knowledge in informal environments provides students with a better transfer of learning, which helps them achieve a deeper understanding of science.

The reliability coefficients revealed by Cronbach's alpha values ranged from 0.688 to 0.834 for the subscales and were 0.950 for the whole scale of the COLSIE survey, which all exceeded the lower limit criterion of 0.65 (DeVellis, 2016). Accordingly, the COLSIE survey, with nine factors (scales), was considered sufficiently reliable and acceptable for assessing primary students' COLSIE.

Table 2
Rotated Factor Loadings and Reliability of the Nine Factors of the COLSIE Survey (n=414).

	F1	F2	F3	F4	F5	F6	F7	F8	F9	Cronbach's alpha
ME1	.661									
ME2	.603									
ME3	.609									.745
ME4	.735									
ME5	.548									
PP1		-.781								.740
PP2		-.710								
RE1			-.571							
RE2			-.555							.688
RE3			-.544							

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	F1	F2	F3	F4	F5	F6	F7	F8	F9	Cronbach's alpha
IK1				.618						
IK2				.588						.767
IK3				.520						
IK4				.611						
IK5				.596						
OA1					.742					.803
OA2					.771					
OA3					.596					
CE1						-.789				
CE2						-.877				.761
CE3						-.413				
AU1							-.512			
AU2							-.498			
AU3							-.473			.822
AU4							-.569			
AU5							-.729			
AU6							-.625			
IO1								.705		
IO2								.589		
IO3								.535		.791
IO4								.402		
IO5								.421		
SE1									.587	
SE2									.747	
SE3									.662	.834
SE4									.728	
SE5									.635	

Notes: ME: *memorizing*; PP: *practising tutorial problems*; RE: *recording by way of notetaking*; IK: *increasing knowledge*; OA: *obtaining authentic experience through activities*; CE: *communicating and explaining*; AU: *applying* and *understanding*; IO: *improving oneself through opportunities*; and SE: *seeing in a new way*.

Primary School Students' Scores on the Nine Scales of the COLSIE Survey

The average scores and standard deviations of the nine scales of the survey in Study II are presented in Table 3. These statistics describe the degree of students' recognition of the nine scales of COLSIE.

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Table 3
Descriptive Statistics and Correlation of Students' Scores on the COLSIE Scales (n=414).

Scale	M	SD	ME	PP	RE	IK	OA	CO	AU	IO
ME	3.434	0.891								
PP	3.628	1.128	.463*							
RE	3.868	0.894	.381*	.331*						
IK	3.875	0.811	.435*	.388*	.528*					
OA	3.765	0.984	.317*	.223*	.478*	.481*				
CE	3.554	0.969	.423*	.358*	.489*	.445*	.468*			
AU	3.672	0.834	.444*	.411*	.462*	.563*	.514*	.540*		
IO	3.718	0.900	.360*	.360*	.426*	.507*	.401*	.458*	.595*	
SE	3.804	0.878	.366*	.328*	.434*	.535*	.456*	.464*	.569*	.624*

Notes: ME: *memorizing*; PP: *practising tutorial problems*; RE: *recording by way of notetaking*; IK: *increasing knowledge*; OA: *obtaining authentic experience through activities*; CE: *communicating and explaining*; AU: *applying* and *understanding*; IO: *improving oneself through opportunities*; SE: *seeing in a new way*; M: mean; and SD: standard deviation. *$p<.01$.

As shown in Table 3, these students scored highest on the scale of *increasing knowledge* (M = 3.875), followed by the scales of *recording by way of notetaking* (M =3.868), *seeing in a new way* (M= 3.804), and *obtaining authentic experience through activities* (M = 3.765). The lowest score was *memorizing* (M = 3.434). Notably, the most frequently chosen main conceptions (*increasing knowledge* and *obtaining authentic experience through activities*) revealed in Study I were confirmed to be widely appreciated by the quantitative analysis in Study II.

Relationships Among Subscales of the COLSIE Survey

Pearson correlation analysis was also conducted for each pair of factors to examine the relationship among students' COLSIE. The results are presented in Table 3. The relationships among the nine subscales of the COLSIE were significantly positively correlated with each other, ranging from 0.223 to 0.624. These significant correlations suggested adequate convergent validity for the COLSIE survey (Netemeyer et al., 2003). That is, the nine subscales revealed by the survey contribute to a common latent construct, i.e., the primary school students' COLSIE.

Discussion

In this study, students' COLSIE were found to be different from the COLS in general and in the laboratory, as evidenced by previous studies (Chiu et al., 2016; Tsai, 2004; Zhao & Thomas, 2016). For easy comparisons, the categories of COLS in various environments are summarized in Figure S.1 in the Appendix, and they are given almost identical names after careful examinations of their original meanings. As shown in Figure S.1, the ten categories identified in the current study showed great commonalities and possessed unique features in comparison with COLS in general and in the laboratory. In the following section, the commonalities and uniqueness of COLSIE among primary school students in Mainland China will be discussed in detail.

Commonalities of COLS

As shown in Figure S.1, this study identified eight common categories of COLSIE that have been revealed in previous studies (Chiu et al., 2016; Tsai, 2004; Zhao & Thomas, 2016). These categories can be classified into three subgroups according to the possible influencing factors.

First, this study found six categories of COLS, i.e., *memorizing*, *practising tutorial problems*, *increasing knowledge*, *applying*, *understanding*, and *seeing in a new way* (see Figure S.1 in the Appendix), which first appeared in Tsai (2004) on Taiwanese high school students' COLS. Accordingly, they are perhaps the essential characteristics of learning science in either formal or informal environments and are thus worth further exploration.

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In addition, the category of *improving oneself through opportunities* was found in this study. This category was first identified in Zhao and Thomas (2016), who investigated Mainland Chinese high school students' COLS. The researchers connected this conception to students' cultural backgrounds. In particular, they believed that students who want to improve themselves when learning science were perhaps influenced by Confucian culture. Collectively, this study also suggested that students' cultural backgrounds should be taken into consideration when analysing students' COLS in both formal and informal environments. As stated earlier, some students reported that learning science in either formal or informal environments was a helpful way to cultivate their abilities and morals to serve well their family and country. Their conceptions were likely influenced by their Chinese cultural background, in particular, Confucianism's advocacy for learning should contribute to good governance. Students from other cultures probably will not associate their learning of science with the goal of serving their family or making contributions to their country. Further studies are encouraged to explore different culturally oriented contexts to better reveal the role of culture on students' views of learning science.

Furthermore, this study found another conception, i.e., *obtaining authentic experience through activities*, which has already been revealed by Chiu et al. (2016) on Taiwan college students' COLS in the laboratory. They argued that learning science in the laboratory could provide students with multisensory experiences, such as observation and operation; thus, students conceptualized learning science as a way of *obtaining authentic experience* (Millar et al., 2003). Lin and Schunn (2016) also suggested that informal environments could provide students with similar experiences. Echoing their study, the category of *obtaining authentic experience through activities* also emerged in the current study. Hence, it is important to promote science learning through various learning contexts and to encourage students to take advantage of observing scientific phenomena or items by engaging in real-life experiences themselves in informal environments.

Uniqueness of COLSIE

This study identified two new categories of COLSIE that had not been revealed in previous studies: *recording by way of notetaking* and *communicating and explaining*. The origins of these two new categories could be related to the way students learning science in informal environments is self-directed, collaborative, nonlinear, and open-ended (Bell et al., 2009; Falk, 2005; Tal, 2012). In other words, these features of informal environments provided students with ample freedom and interaction to engage in science practices, such as "obtaining, evaluating, and communicating information" (National Research Council, 2013, p. 382).

First, students conceptualize learning science in informal environments as *recording by way of notetaking*, perhaps because they can have a high degree of autonomy in an informal learning context. Scientific investigation and observation may be conducted in the laboratory or in the field. A primary goal of scientific investigation and observation of the world is to systematically describe the world, which requires identifying what is to be recorded (National Research Council, 2012). Students can fully experience the learning process by recording the subjects and results of their investigations in informal environments because of their high degree of autonomy, which they may find difficult to receive in a formal classroom environment. Therefore, students may conceptualize learning science in informal environments as *recording by way of notetaking*.

In addition, students value *communicating and explaining* in learning science in informal environments, as "scientific disciplinary knowledge is constructed, communicated, and assessed through language" (Reveles et al., 2007, p. 469). Science education examines how people learn to talk and write the language of science and meaningfully and cooperatively engage in various activities (Lemke, 2001). The collaborative nature of learning science in informal environments provided students with ample opportunities to communicate their ideas clearly and persuasively in oral and written languages. In this study, students reported that they were able to share their science-related knowledge freely with others, which was something that they rarely do in formal classroom settings. The practice of communication also helps students' understanding of science. Thus, these ideas may strengthen students' impression that learning science in informal environments involves *communicating and explaining*.

Categories of COLS which were Not Revealed in this Study

This section examines some categories of COLS that were revealed by previous studies but did not emerge in this study. First, *testing* and *working hard* were identified in Tsai (2004) and Zhao and Thomas (2016) but were absent in the current study. In their studies, participants were high school students who worked extremely hard because

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they hoped to achieve a proficient performance in the college entrance examination. However, in the current study, participants were primary school students who were not exam driven because they did not have to take high-stakes entrance examinations when attending middle school as a result of the nine-year compulsory education policy in Mainland China. It also explains why primary students showed significantly lower academic stress (e.g., stresses of learning content and examination) than secondary school students in Mainland China (Long et al., 2013).

In addition, *listening to the teacher* was previously identified in the formal science learning environment (Zhao & Thomas, 2016). However, in informal environments, students learn science in a self-directed manner, in which guidance from adults (e.g., teachers) is always ruled out (Bell et al., 2009). Thus, it seems reasonable that this category was absent in this study.

Finally, three categories of COLS in the laboratory, *examining prior knowledge*, *reviewing prior learning profiles*, and *acquiring manipulative skills,* were not identified in the current study (Chiu et al., 2016). Their absence could be explained by the apparent student age differences and the indirect connection between formal and informal environments. *Examining prior knowledge* and *reviewing prior learning profiles* were considered metacognitively orientated, which referred to an individual's capacity to connect with prior knowledge and other experiences, as well as to examine the gap between theory and practice (Chiu et al., 2016). However, primary school students in this study do not have these two metacognitively oriented categories because they are at the stage of having a lower level of metacognition (Vukman, 2005) compared with the college students investigated by Chiu et al. (2016). It is also possible that these students find it challenging to tap into knowledge they learned previously in the science classroom. There is a direct linkage between the science classroom and laboratory, and students can easily connect with prior declarative and procedural knowledge and their experience in the laboratory. However, primary school students may struggle to make this connection because of the nonlinear and open-ended manner of informal science learning (Bell et al., 2009).

Limitations and Suggestions for Future Studies

In this study, the ten categories of COLSIE emerged through interview data gathered from students in three primary schools located in South China. During the sampling process, these schools were selected purposively to meet the requirement of diverse responses. However, careful consideration is necessary when generalizing the results of this study to other student populations in Mainland China. In addition, this study did not analyse the relationship between students' prior experience of informal science learning and their COLSIE. It would be beneficial to provide evidence for cross validation, i.e., do students who have more experience of informal science learning tend to hold more constructivist COLSIE?

Some suggestions derived from this study could also warrant future study. First, the ten qualitatively different categories of COLSIE found in this study could serve as a foundation for researchers to conduct relevant studies. Guided by this framework, future studies are encouraged to further investigate students' COLSIE in diverse specific informal environments, e.g., informal home science, semiformal science, nature, and museums (Lin & Schunn, 2016). Second, the COLSIE survey developed in the current study can be used to explore the relationships among students' conceptions, approaches, and outcomes of learning science in informal environments (e.g., Lee et al., 2008; Zheng et al., 2018). Finally, it will be beneficial to conduct research investigating the relationships between students' COLSIE and other adults' COLSIE, e.g., their parents and tour guides in the museum (Lin et al., 2014).

Conclusions

Given the importance of learning science in informal environments to students' academic achievement, this study explored COLSIE among a group of primary school students in Mainland China. Overall, ten hierarchical categories of COLSIE were identified in Study I through phenomenographic analysis. Notably, many of these primary school students perceived their COLSIE as *increasing knowledge* and *obtaining authentic experience through activities*. To assess students' COLSIE, a specific survey with sufficient reliability and validity was developed in Study II. Exploratory factor analysis revealed nine factors that matched the ten categories except for the initial categories of *applying* and *understanding*. Overall, the initial ten categories were supported by the quantitative analysis in Study II.

It is worth mentioning that, in different environments, students may show different degrees of agreement with the eight common categories of COLS. According to Study I, students expressed their main conceptions in *obtaining authentic experience through activities* and *increasing knowledge*, which may not necessarily be the same as their main conceptions in formal environments. In other words, a student may show more agreement with a conception

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in informal environments than they do in formal environments or vice versa. Accordingly, researchers are encouraged to incorporate the COLSIE survey developed in the current study to better investigate students' COLS in both formal and informal environments.

Furthermore, the current study identified two new categories of COLSIE that had not been revealed in previous studies: *recording by way of notetaking* and *communicating and explaining*. Notably, these two unique conceptions highlight the benefits of learning science in informal environments for strengthening students' impressions and values of science practices. Informed by the results of this study, future studies can explore whether students who show more agreement with these two conceptions tend to prefer doing practical work and participating in science inquiry activities.

Previous studies have primarily focused on students' science learning in formal environments. The current study provided an additional perspective regarding students' science learning by providing an in-depth description of students' views of learning science in informal environments. Overall, the findings draw attention to the complex outcomes of students' COLS in different environments. Students' COLS, originally developed in different environments, may eventually form a coherent mind system of learning science, which will play an essential role in students' subsequent approaches to and outcomes of learning science.

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Declaration of Interest

Authors declare no competing interest.

References

Alexander, J. M., Johnson, K. E., & Kelley, K. (2012). Longitudinal analysis of the relations between opportunities to learn about science and the development of interests related to science. *Science Education*, *96*(5), 763–786. https://doi.org/10.1002/sce.21018

Anderson, D., & Ellenbogen, K. M. (2012). Learning science in informal contexts – epistemological perspectives and paradigms. In Fraser B., Tobin K., & McRobbie C. (Eds), *Second international handbook of science education* (pp. 1179-1187). Springer. https://doi.org/10.1007/978-1-4020-9041-7_78

Aubusson, P., Griffin, J., & Kearney, M. (2012). Learning beyond the classroom: Implications for school science. In Fraser B., Tobin K., & McRobbie C. (Eds), *Second international handbook of science education* (pp. 1123-1134). https://doi.org/10.1007/978-1-4020-9041-7_74

Bell, P., Bruce Lewenstein, Andrew W. Shouse, & Michael A. Feder (Eds.). (2009). *Learning science in informal environments: People, places, and pursuits*. The National Academies Press. https://doi.org/10.17226/12190

Boulton-Lewis, G. M., Marton, F., Lewis, D. C., & Wilss, L. A. (2000). Learning in formal and informal contexts: Conceptions and strategies of Aboriginal and Torres Strait Islander university students. *Learning and Instruction*, *10*(5), 393–414. https://doi.org/10.1016/S0959-4752(00)00005-0

Chiou, G.-L., Liang, J.-C., & Tsai, C.-C. (2012). Undergraduate students' conceptions of and approaches to learning in Biology: A study of their structural models and gender differences. *International Journal of Science Education*, *34*(2), 167–195. https://doi.org/10.1080/09500693.2011.558131

Chiu, Y.-L., Lin, T.-J., & Tsai, C.-C. (2016). The conceptions of learning science by laboratory among university science-major students: Qualitative and quantitative analyses. *Research in Science & Technological Education*, *34*(3), 359–377. https://doi.org/10.1080/02635143.2016.1222518

Dahlin, & Regmi, M. P. (1997). Conceptions of learning among Nepalese students. *Higher Education*, *33*(4), 471–493. https://doi.org/10.1023/A:1002992411868

DeVellis, R. F. (2016). *Scale development: Theory and applications* (4th ed.). Sage publications.

Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. (2007). *Taking science to school: Learning and teaching science in Grades K-8*. The National Academies Press.

Ellenbogen, K. (2003). Free-choice science education: How we learn science outside of school. *Science Education*, *87*(3), 449–452. https://doi.org/10.1002/sce.10095

https://doi.org/10.33225/jbse/21.20.407

Falk, J. H. (2005). Free-choice environmental learning: Framing the discussion. *Environmental Education Research*, *11*(3), 265–280. https://doi.org/10.1080/13504620500081129
Gao, L., & Watkins, D. A. (2002). Conceptions of teaching held by school science teachers in P.R. China: Identification and cross-cultural comparisons. *International Journal of Science Education*, *24*(1), 61–79. https://doi.org/10.1080/09500690110066926
Holmes, J. A. (2011). Informal learning: Student achievement and motivation in science through museum-based learning. *Learning Environments Research*, *14*(3), 263–277. https://doi.org/10.1007/s10984-011-9094-y
Lee, M.-H., Johanson, R. E., & Tsai, C.-C. (2008). Exploring Taiwanese high school students' conceptions of and approaches to learning science through a structural equation modeling analysis. *Science Education*, *92*(2), 191–220. https://doi.org/10.1002/sce.20245
Lee, M.-H., Liang, J.-C., Wu, Y.-T., Chiou, G.-L., Hsu, C.-Y., Wang, C.-Y., Lin, J.-W., & Tsai, C.-C. (2019). High school students' conceptions of science laboratory learning, perceptions of the science laboratory environment, and academic self-efficacy in science learning. *International Journal of Science and Mathematics Education*. https://doi.org/10.1007/s10763-019-09951-w
Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, *38*(3), 296–316. https://doi.org/10.1002/1098-2736(200103)38:3<296::AID-TEA1007>3.0.CO;2-R
Li, W.-T., Liang, J.-C., & Tsai, C.-C. (2013). Relational analysis of college chemistry-major students' conceptions of and approaches to learning chemistry. *Chemistry Education Research and Practice*, *14*(4), 555–565. https://doi.org/10.1039/C3RP00034F
Lin, C.-C., & Tsai, C.-C. (2009). The relationships between students' conceptions of learning engineering and their preferences for classroom and laboratory learning environments. *Journal of Engineering Education*, *98*(2), 193–204. https://doi.org/10.1002/j.2168-9830.2009.tb01017.x
Lin, C.-L., Tsai, C.-C., & Liang, J.-C. (2012). An investigation of two profiles within conceptions of learning science: An examination of confirmatory factor analysis. *European Journal of Psychology of Education*, *27*(4), 499–521. https://doi.org/10.1007/s10212-011-0092-3
Lin, H.-M., & Tsai, C.-C. (2008). Conceptions of learning management among undergraduate students in Taiwan. *Management Learning*, *39*(5), 561–578.
Lin, H.-M., & Tsai, C.-C. (2013). The development of the conceptions of learning management inventory. *Studies in Higher Education*, *38*(5), 741–757. https://doi.org/10.1080/03075079.2011.593621
Lin, P.-Y., & Schunn, C. D. (2016). The dimensions and impact of informal science learning experiences on middle schoolers' attitudes and abilities in science. *International Journal of Science Education*, *38*(17), 2551–2572. https://doi.org/10.1080/09500693.2016.1251631
Lin, T.-J., Lee, M.-H., & Tsai, C.-C. (2014). The commonalities and dissonances between high-school students' and their science teachers' conceptions of science learning and conceptions of science assessment: A Taiwanese sample study. *International Journal of Science Education*, *36*(3), 382–405. https://doi.org/10.1080/09500693.2013.780317
Long, A., Wei, F., & Jin, X. (2013). Measurement and attribution model construction on academic stress of primary and secondary school students [中小学生学习压力的测度及归因模型构建]. *Journal of Educational Studies [教育学报]*, *9*(01), 121–128.
Marton, F. (1981). Phenomenography—Describing conceptions of the world around us. *Instructional Science*, 177–200.
Marton, F., & Booth, S. (1997). *Learning and awareness*. Lawrence Erlbaum Associates.
Marton, F., Dall'Alba, G., & Beaty, E. (1993). Conceptions of learning. *International Journal of Educational Research*, *19*(3), 277–300.
Millar, R., Tiberghien, A., & Maréchal, J.-F. (2003). Varieties of labwork: A way of profiling labwork tasks. In D. Psillos & H. Niedderer (Eds.), *Teaching and Learning in the Science Laboratory* (Vol. 16, pp. 9–20). Kluwer Academic Publishers. https://doi.org/10.1007/0-306-48196-0_3
National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. The National Academies Press.
National Research Council. (2013). *Next generation science standards: For states, by states*. The National Academies Press. https://doi.org/10.17226/18290
Negovan, V., Sterian, M., & Colesniuc, G.-M. (2015). Conceptions of Learning and Intrinsic Motivation in Different Learning Environments. *Procedia - Social and Behavioral Sciences*, *187*, 642–646. https://doi.org/10.1016/j.sbspro.2015.03.119
Netemeyer, R., Bearden, W., & Sharma, S. (2003). *Scaling procedures: Issues and applications*. SAGE. https://doi.org/10.4135/9781412985772
Philip, T. M., & Azevedo, F. S. (2017). Everyday science learning and equity: Mapping the contested terrain. *Science Education*, *101*(4), 526–532. https://doi.org/10.1002/sce.21286
Reveles, J. M., Kelly, G. J., & Durán, R. P. (2007). A sociocultural perspective on mediated activity in third grade science. *Cultural Studies of Science Education*, *1*(3), 467–495. https://doi.org/10.1007/s11422-006-9019-8
Richardson, J. T. E. (1999). The concepts and methods of phenomenographic research. *Review of Educational Research*, *69*(1), 53–82. https://doi.org/10.3102/00346543069001053
Saljo, R. (1979). *Learning in the learner's perspective. I. Some common-sense conceptions. (Report No. 76)*. University of Göteborg, Institute of Education.
Shaby, N., & Vedder-Weiss, D. (2019). Science identity trajectories throughout school visits to a science museum. *Journal of Research in Science Teaching*, tea.21608. https://doi.org/10.1002/tea.21608
Tal, T. (2012). Out-of-school: Learning experiences, teaching and students' learning. In *Second International Handbook of Science Education* (Vol. 1–24). Springer.
Tang, X., & Zhang, D. (2020). How informal science learning experience influences students' science performance: A cross-cultural study based on PISA 2015. *International Journal of Science Education*, *0*(0), 1–19. https://doi.org/10.1080/09500693.2020.1719290
Tsai, C.-C. (2004). Conceptions of learning science among high school students in Taiwan: A phenomenographic analysis. *International Journal of Science Education*, *26*(14), 1733–1750. https://doi.org/10.1080/0950069042000230776

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Tsai, C.-C. (2009). Conceptions of learning versus conceptions of web-based learning: The differences revealed by college students. *Computers & Education*, *53*(4), 1092–1103. https://doi.org/10.1016/j.compedu.2009.05.019

Tsai, C.-C., Jessie Ho, H. N., Liang, J.-C., & Lin, H.-M. (2011). Scientific epistemic beliefs, conceptions of learning science and self-efficacy of learning science among high school students. *Learning and Instruction*, *21*(6), 757–769. https://doi.org/10.1016/j.learninstruc.2011.05.002

Tsai, C.-C., & Kuo, P.-C. (2008). Cram school students' conceptions of learning and learning science in Taiwan. *International Journal of Science Education*, *30*(3), 353–375. https://doi.org/10.1080/09500690701191425

Vedder-Weiss, D., & Fortus, D. (2011). Adolescents' declining motivation to learn science: Inevitable or not? *Journal of Research in Science Teaching*, *48*(2), 199–216. https://doi.org/10.1002/tea.20398

Vukman, K. B. (2005). Developmental differences in metacognition and their connections with cognitive development in adulthood. *Journal of Adult Development*, *12*(4), 211–221. https://doi.org/10.1007/s10804-005-7089-6

Zhao, Z., & Thomas, G. P. (2016). Mainland Chinese students' conceptions of learning science: A phenomenographic study in Hebei and Shandong Provinces. *International Journal of Educational Research*, *75*, 76–87. https://doi.org/10.1016/j.ijer.2015.11.008

Zheng, L., Dong, Y., Huang, R., Chang, C.-Y., & Bhagat, K. K. (2018). Investigating the interrelationships among conceptions of, approaches to, and self-efficacy in learning science. *International Journal of Science Education*, *40*(2), 139–158. https://doi.org/10.1080/09500693.2017.1402142

Zimmerman, H. T., Land, S. M., Maggiore, C., & Millet, C. (2019). Supporting children's outdoor science learning with mobile computers: Integrating learning on-the-move strategies with context-sensitive computing. *Learning, Media and Technology*, *44*(4), 457–472. https://doi.org/10.1080/17439884.2019.1667823

Appendix

Conceptions of Learning Science in Informal Environments Survey

Items presented in the following were translated from Chinese to English by the authors. An additional bilingual researcher unfamiliar with the current research was asked to translate the English version of the survey back to Chinese to ensure translation correctness. The back-translated survey was then compared against the original survey for further revision and refinement. No misinterpretations were detected, and hence, the translation process was finalised. The items modified from previous studies are marked with an asterisk (*). In addition, some items were underlined, as they were suggested to be dropped based on EFA results.

Memorizing

ME1*. Learning science in informal environments means memorizing some concepts and facts relevant to science.

ME2*. Learning science in informal environments means memorizing some science terminologies and being able to use them to answer questions from others.

ME3. Learning science in informal environments means memorizing the procedures and the results of the experiments.

ME4. Learning science in informal environments means memorizing the knowledge by heart and being able to repeat it.

ME5. Learning science in informal environments means learning by heart and leaving a powerful mark on my memories.

<u>ME6</u>. Learning science in informal environments means memorizing what someone else said.

Practising tutorial problems

PP1. Learning science in informal environments means practising tutorial problems to check how well I master certain knowledge

PP2*. Learning science in informal environments means practising tutorial problems to strengthen what I learned.

<u>PP3</u>*. Learning science in informal environments means participating in various calculating and tutorial problem-solving activities.

<u>PP4</u>*. Learning science in informal environments means repeatedly doing calculation and practising tutorial problems.

<u>PP5</u>. Learning science in informal environments means finishing exam sheets or homework assigned by others.

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Recording by way of notetaking

RE1. Learning science in informal environments means taking notes of what I observed.
RE2. Learning science in informal environments means taking notes of the results.
RE3. Learning science in informal environments means taking notes of some important information.
RE4. Learning science in informal environments means taking notes of what interests me.
RE5. Learning science in informal environments means recording my reflection.

Increasing knowledge

IK1*. Learning science in informal environments means learning something new.
IK2. Learning science in informal environments means obtaining various types of science-related knowledge.
IK3. Learning science in informal environments means supplementing what I learned in classroom learning.
IK4. Learning science in informal environments means obtaining knowledge about modern technology.
IK5. Learning science in informal environments means learning extra knowledge beyond the classroom.
IK6. Learning science in informal environments means obtaining knowledge about animals and plants.

Obtaining authentic experience through activities

OA1. Learning science in informal environments means obtaining hands-on experience.
OA2. Learning science in informal environments means gaining authentic experience of science phenomena.
OA3*. Learning science in informal environments means observing the process and the results of science experiments.
OA4*. Learning science in informal environments is to acquire practical experience by doing experiments.

Communicating and explaining

CE1. Learning science in informal environments means communicating with peers.
CE2. Learning science in informal environments enables me to communicate with classmates better.
CE3. Learning science in informal environments means sharing scientific knowledge with my classmates.

Applying and Understanding

AU1*. Learning science in informal environments means applying what I already know to problems that I have never encountered before.
AU2. Learning science in informal environments means explaining new science phenomena using what I learned.
AU3*. Learning science in informal environments helps me understand how science knowledge was developed.
AU4. Learning science in informal environments provides me with a profound understanding of science.
AU5*. Learning science in informal environments helps me understand the essence of science knowledge.
AU6*. Learning science in informal environments helps me explore the process by which scientists made scientific discoveries.
AU7. Learning science in informal environments means applying what I already know to problems that I encountered in real life.
AU8. Learning science in informal environments means practising my knowledge to solve practical problems.
AU9. Learning science in informal environments means applying scientific knowledge to make something new.
AU10. * Learning science in informal environments helps me understand the connections between scientific concepts.
AU11. * Learning science in informal environments helps me understand the meanings of scientific theories and formulas.

Improving oneself through opportunities

IO1. Learning science in informal environments helps boost my intelligence (IQ) and ability.
IO2. Learning science in informal environments helps me identify my shortcomings and find ways to cope with them.
IO3. Learning science in informal environments helps me build good study habits towards learning science.
IO4. Learning science in informal environments means bringing self-improvement and benefits to my family in the future.

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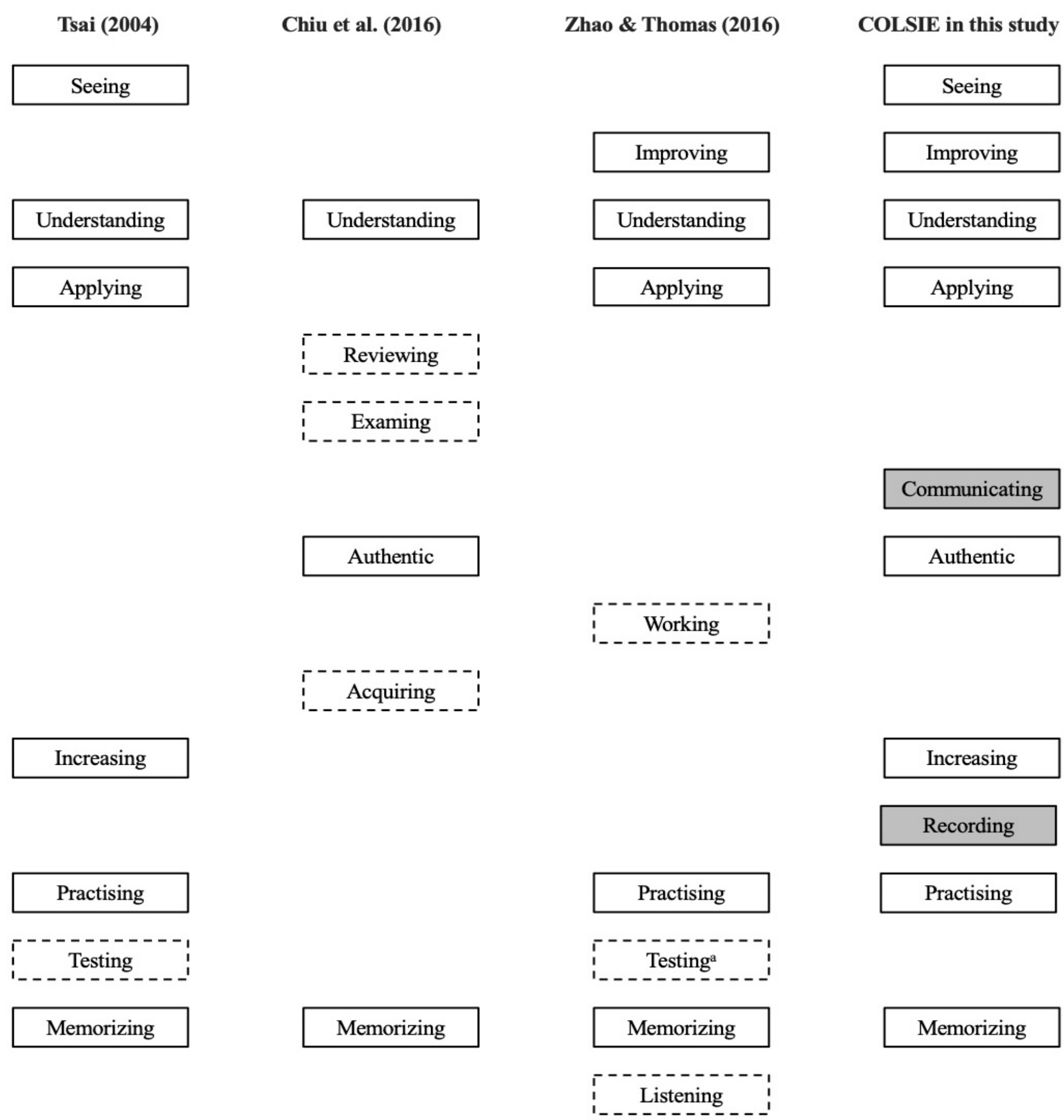
IO5. Learning science in informal environments means better serving my country when I grow up.
IO6. Learning science in informal environments means making global contributions when I grow up.

Seeing in a new way

SE1. Learning science in informal environments expands my vision for the world.
SE2. Learning science in informal environments changed my insights about science.
SE3. Learning science in informal environments helps me explore the world.
SE4*. Learning science in informal environments changed the ways I look at nature.
SE5. Learning science in informal environments enabled me to approach science phenomena from different perspectives.
SE6. * Learning science in informal environments brought me new ways of observing natural phenomena.

Figure S.1
Commonalities and Uniqueness of COLS Revealed by Different Studies



Note: White squares plotted with a solid line (e.g., *memorizing*) represent the categories of COLSIE that have been revealed by previous studies (common conceptions); grey squares plotted with a solid line (e.g., *recording by way of notetaking*) show the

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unique categories of COLSIE that have not been revealed in previous studies; and white squares plotted with a dotted line (e.g., *testing*) are the categories that have been revealed by previous studies but not in COLSIE. In Zhao and Thomas's (2016) study, the category of COLS named *learning science as attending to exams* is similar to the conception of *testing* in other studies. In Zhao and Thomas's (2016) study, there was a category of COLS named *doing problems*, which include few subcategories, e.g., *doing problems as practising* (*practising*) and *doing problems as applying* (*applying*).

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BIBLIOMETRIC ANALYSIS OF THE INTERNATIONAL SCIENTIFIC PRODUCTION ON ENVIRONMENTAL EDUCATION

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Abstract. *Environmental Education has become over recent decades an emerging area of knowledge; its evolution has been conditioned not only by different regional dynamics, but also by international guidelines and trends. Therefore, the literature reports multiple and diverse pedagogical, curricular and transdisciplinary approaches to this topic. Likewise, studies on the dynamics and trends in the generation and production of knowledge are relevant to both teachers and researchers in every field of knowledge. In this sense, it is presented a bibliometric study that aims to analyse the international scientific production on Environmental Education on the Web of Science (WoS) within the categories Education and Educational Research and Education, Scientific Disciplines for the last two decades (2000-2019). The information obtained was analysed using different bibliometric techniques, like descriptive statistics, degree of collaboration and co-occurrence maps generated by VOSviewer (version 1.6.15) software. The results show the accelerated increase in the production of knowledge in this area, they present the main research contexts, as well as some educational and research perspectives. Also, the collaboration between authors and universities was identified.*

Keywords: *bibliometrics analysis, environmental education, scientific education, scientific production*

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Introduction

Environmental Education was conceived in the late 60s, when what it is known today as the Club of Rome (1968) was founded. Club of Rome was a non-governmental organization formed by businessmen, scientists, and politicians from 52 countries. The main principle of this community was to show that the current growth patterns would lead to an imminent depletion of natural resources, to the erosion of ecosystems and to regional and global environmental crises. For this reason, Club of Rome ordered a report from a group of researchers at the Massachusetts Institute of Technology (MIT), led by Meadows (Meadows et al., 1972). The MIT report stated that any deliberate attempt to achieve a lasting and rational state of balance, made through planning rather than through chance or catastrophe, should find its ground in a change of values and goals individually, nationally, and globally. Therefore, this event revealed the need to develop a full-scale strategy to face major problems, including in particular, those that represent humankind's relationship with environment.

Therefore, 1972 stood out as a year of changes or at least proposals for changes; in fact, it was the first significant moment regarding Environmental Education, because The United Nations Conference on the Human Environment was held in Stockholm this year (United Nations, 1973). This was the first conference about environment and important global environmental problems were discussed there. Furthermore, the Conference on Environmental Education held in Tbilisi (UNESCO, 1978) pointed to the need to transform the educational systems and to rethink them considering environmental problems, equity and social and ecological justice, and the world as a complex system. Likewise, Tbilisi Declaration (UNESCO, 1978) requested the member states to include in their educational policies measures to incorporate into their educational systems environmental education contents and strategies based on the general objectives and guidelines established there; also, the educational authorities were invited to reinforce and promote reflection, research, and innovation in Environmental Education.

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In the following years, different elements were provided for an international strategy of education and training in the environment field; principles, characteristics, typologies, agents involved, and research guidelines were recognized in order to answer the environmental problems of the moment (UNESCO, 1987). However, it was in the Brundtland report (World Commission on Environment and Development, 1987) where the concept of sustainable development was developed and one of the strongest lines in Environmental Education began to consolidate: Education for Sustainable Development (ESD). This fact and the Conference of Río (Guimaraes, 1992) spread a very relevant message: there can be no economic growth without a sustainable environment, and education, at all levels, is where sustainability should be promoted.

ESD (UNESCO, 2002) allows every person to acquire the knowledge, skills, attitudes and values needed to build a sustainable future (Novo, 2009). Instructional education could be reformulated around sustainability, in this sense, Vilches Peña and Gil-Pérez (2016) considered that transition to sustainability should not be seen, nor considered at the educational level, as a bet for the future that requires sacrifices now: it is, on the contrary, a well-founded strategy to solve the problems that the humankind is already experiencing. It is about involving teachers, students and citizens in general, to satisfy the current needs from the humankind (not just from a minority), without harming the future. Something that the current recipes to "get out of the crisis", which is not only economic, cannot achieve.

Therefore, international guidelines have been adopted in multiple contexts - for example, the 2030 Agenda or the Sustainable Development Goals-, and public policies have been developed to strengthen and promote environmental education and to give it a transdisciplinary connotation. This has favoured linking environmental topics with different areas of knowledge in several educational contexts (formal, non-formal or informal). In addition, research studies which theorize, generate and systematize different experiences, have appeared, and studying them allows knowing the different patterns of knowledge generation in this field.

From this perspective, Environmental Education gives relevance to education, participation, research, and evaluation. Likewise, some recurring actions carried out are: collaboration in the creation and maintenance of infrastructures and networks of information and documentation for the use of associations; creation of local, regional, national and international associations that allow a more active social presence; establishment of cooperation agreements between associations in order to develop common initiatives, design and make good use of resources and materials, or coordinate effective and long-term programs; finally, promotion for the incorporation of environmental education in international development cooperation programs, in collaboration with organizations and universities from different countries.

In this sense, the literature allows recognizing the need for a deep conceptualization in Environmental Education and transcending from merely informative processes to others that transform the educational reality and allow systemic and critical thinking, participation and collaboration, and without a doubt, emotional bonding, in formal contexts (educational centres), as well as in non-formal ones. According to different authors, the increasing interest in environmental issues has also increased the production of knowledge on this field (Abraham et al., 2015; González & Puente, 2010; Medina Arboleda & Páramo, 2014). In fact, Environmental Education is nowadays considered as a relevant and interesting research and academic field. This has led to the publication of different documents, including reflections, literature reviews and empirical research.

Maz-Machado et al. (2020) argued about the need for bibliometric studies that analyse the dynamics and trends in the generation and production of knowledge. They considered that this kind of studies allows knowing the state of a field of knowledge and the production patterns of countries, regions or institutions, recognizing its strengths and even motivating political or scientific measures. In addition, bibliometric studies allow knowing more about patterns of research of a field by identifying for example the main countries, authors, institutions, keywords, research clusters, topics addressed, collaboration networks, etc. (González-Alcaide et al., 2018; Maz-Machado et al., 2015).

In this sense, literature review and bibliometric studies in Environmental Education allow reconstructing the history of the research in the field in local and global contexts, knowing the prevailing pedagogical trends, the epistemological and methodological obstacles, etc. Therefore, in recent years different bibliometric studies about Environment and Environmental Education have been made worldwide, for example Abraham et al. (2015), Hallinger and Chatpinyakoop (2019), Prosser Bravo and Romo-Medina (2019), etc.

In order to do this kind of studies, Medina-Arboleda and Páramo (2014) suggested expanding the inclusion of journals from different areas of knowledge in the searches, considering that environment implies transdisciplinarity. The same opinion about transdisciplinarity in the field manifested Papadimitriou and Kidman (2012). They analysed the journal *International Research in Geographical and Environmental Education* and they stated that although themes like teacher education, values and attitudes, inquiry and problem-solving were recurrent through

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the years, the thematic diversity of articles was high.

On the other hand, Onopriienko et al. (2021) stated that:

> Conducting a bibliographic analysis according to the keywords "environmental education" it can be argued that the diversity of views on this thematic cluster is high. At the same time, each author in one way or another mentions the dialogue between man and nature, which is impossible without environmental education of young people and adults. Environmental education of adults is becoming especially relevant and requires qualitative changes, the latest methods and approaches, the use of international experience. (p. 6)

These studies show the growing interest for bibliometric studies in Environmental Education and the different views that these studies can offer. All things considered, this research aimed to know the international annual production in Education and Environment (E&E); to identify the most productive universities on this field; to know the topics with the greatest presence in the analysed documents according to their descriptors and the pattern of co-occurrences in the articles; to determine the degree of collaboration in authorship; and finally, to identify the journals included in SSCI that publish E&E documents.

Research Methodology

General Background and Sample Selection

This research is an exploratory and descriptive study. In March 2020, WoS was consulted, and the *Social Sciences Citation Index* (SSCI) database was selected from the main collection. Later, it was searched within the category Field of WoS the term <<Environmental Education>> from 2000 to 2019. 10855 documents were obtained corresponding to the entire database SSCI. Then, the data was refined by choosing the categories *Education & Educational Research* and *Education, Scientific Disciplines*, in order to ensure that all documents were related to educational aspects. Finally, using this filter, 2419 documents were obtained.

The described filter allowed ensuring that all the documents correspond to Education and Environmental Education themes. However, due to this filter other documents that address this topic may have been left out, therefore, the study is of a sample nature.

Instrument and Procedures and Data Analysis

All the considered documents were systematized in an ad hoc database, using Microsoft Office 2019 software (Access and Excel). Then, a process of standardization of the names of the educational institutions was carried out, due to the fact that different variants were found for the same institution.

The variables taken into account were: year, affiliation of the authors, name of the journal, number of authors per document, and descriptors; both, the ones defined by the authors and the Keywords plus given by WoS based on the cited references (Mangan, 2019). Then, the frequencies of each of the variables were extracted. Furthermore, the co-occurrence network (co-words) in the documents for the descriptors and Keywords plus was determined.

To assign the authorship of each document, all individuals identified as authors in the selected documents were included and counted equally. Only personal (rather than corporate) authors were included in this study.

In order to determine the collaboration patterns in authorship, the number of authors of each document was counted and then, to find the Degree of Collaboration (DC), the formula proposed by Subramanyam (1983) was used. This indicator has been used in various studies in science and social sciences (Pinto et al., 2015). Thus, for a collection k of articles published in a journal, these indicators are defined as:

$$DC= 1- f_1/N$$

Where $0 \leq DC \leq 1$.

f_j = Number of articles with exactly j authors in a collection k, so f_1 is the number of articles with exactly one author in a collection k.

N = Total number of articles in k.

The affiliation of the signing authors was taken into account to identify the collaboration that occurs between universities and then, the collaboration network was represented using the VOSviewer version 1.6.15 software

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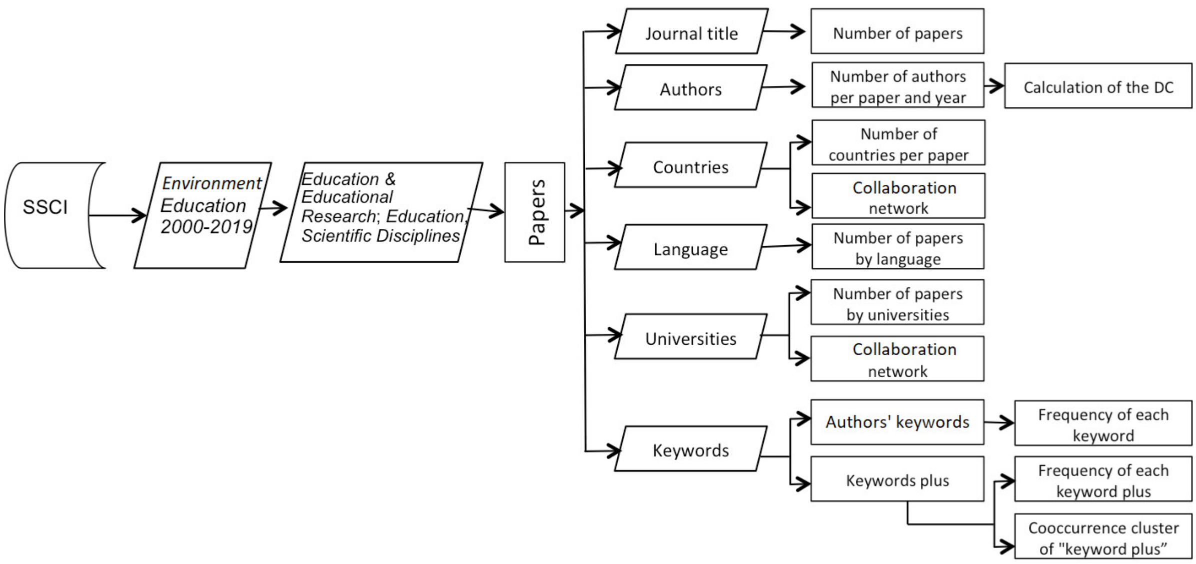
(Van Eck & Waltman, 2020). Collaboration between countries was determined based on the number of authors from each country.

The entire methodological process followed in each step is explained in the following data processing diagram (Figure 1).

Figure 1
Diagram of the Data Processing



Research Results

The analysis shows a total of 2419 documents about E&E indexed in the two SSCI categories, *Education & Educational Research* and *Education*, *Scientific Disciplines*. In relation to the language of publication, 96.7% of the documents were published in English (Table 1); this agrees with the fact that English is the main language for the international dissemination of scientific knowledge in this database.

Table 1
Language of Publication of the Documents Analysed

Language	*N*	%
English	2340	96.73
Spanish	50	2.07
Turkish	17	0.70
Other	12	0.50
Total	2419	100.00

The year of publication of the documents revealed an increase in the production over the 20 years analysed, because only 10 documents were published in 2000 while 319 were published in 2019. However, this increase has not been consistent over the years (Figure 2). For example, from 2005 to 2012 there was a gradual increase in production, then, the production decreased slightly until 2015, since then it has increased and in 2019 the maximum production, until that moment, was achieved. To sum up, the behaviour of the production can be represented with a linear model with an R=0.912 adjustment.

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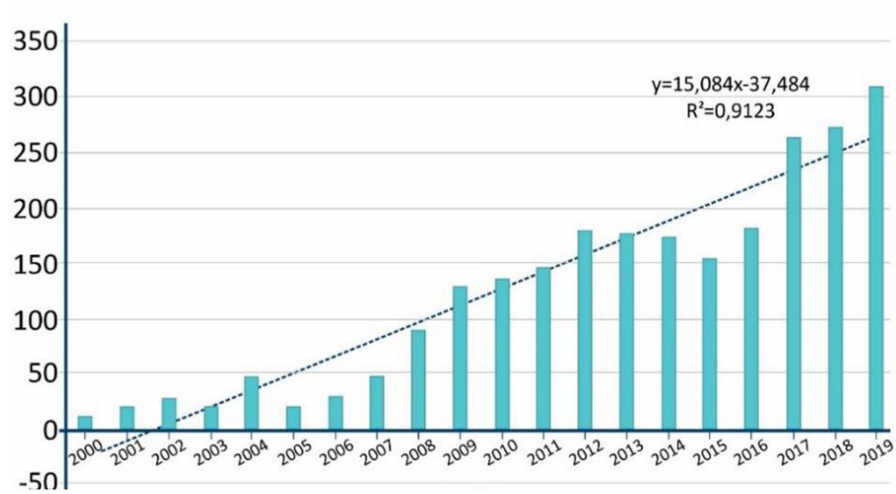
Figure 2
Annual Production on Environmental Education in SSCI (2000-2019)



There may be several reasons behind this behaviour. For example, it could be influenced by national and international events about environment and environmental education or by emerging lines of research.

Considering every document included in the analysis, articles are the most common form of publication, they represent 92.02% of all documents (Table 2).

Table 2
Type of Publication of the Documents Analysed

Type of Document	*N*	%
Article	2226	92.02
Editorial material	71	2.94
Review	69	2.85
Proceedings paper	32	1.32
Book	14	0.58
Others	7	0.29
Total	2419	100.00

Research articles were published in 235 journals. 64.3% of these journals are from the United States of America, 17.9% from the Netherlands and 3.8% from Turkey. Table 3 shows the 20 journals which have published more documents about E&E, they published 60.2% of the total documents. It is noteworthy that among these journals, in 11th position, it was found *Enseñanza de las Ciencias*, which is published in Spain and its language of publication is Spanish.

Table 3
Top 20 WoS Journals that Publish on Environmental Education (2000-2019)

Journal	N	%
Environmental Education Research	557	23.03
Journal of Environmental Education	189	7.81
International Journal of Sustainability in Higher Education	154	6.37

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Journal	N	%
International Journal of Science Education	90	3.72
Journal of Geography in Higher Education	53	2.19
Eurasia Journal of Mathematics Science and Technology Education	40	1.65
Science Education	37	1.53
Research in Science Education	35	1.45
Journal of Research in Science Teaching	32	1.32
Journal of School Health	30	1.24
Enseñanza de las Ciencias	28	1.16
Health Education Research	27	1.12
Higher Education	25	1.03
Journal of Science Education and Technology	25	1.03
International Journal of Educational Development	24	0.99
Journal of Baltic Science Education	24	0.99
Nurse Education Today	24	0.99
Journal of Biological Education	22	0.91
Bmc Medical Education	21	0.87
Journal of Nutrition Education and Behaviour	20	0.83

Considering the origin of the authors of the documents included in the analysis, the study found 91 different countries. More than a third of the publications on E&E come from the United States of America, as Table 4 shows. Then, documents come also from Australia and the United Kingdom, which have a similar number of documents published (219 and 218 respectively). Among the most productive countries from Latin America are included Brazil with 47 documents, Mexico with 16 documents and Colombia with 6 documents.

Table 4
Top 20 Countries with the Highest Scientific Production on Environmental Education

Country	*N*	%
USA	813	33.61
Australia	219	9.05
United Kingdom	218	9.01
Canada	177	7.32
Turkey	136	5.62
Sweden	118	4.88
Spain	108	4.46
China	77	3.18
Germany	75	3.10
Netherlands	67	2.77
Israel	65	2.69
Taiwan	61	2.52
Brazil	47	1.94
New Zealand	44	1.82
South Africa	43	1.78

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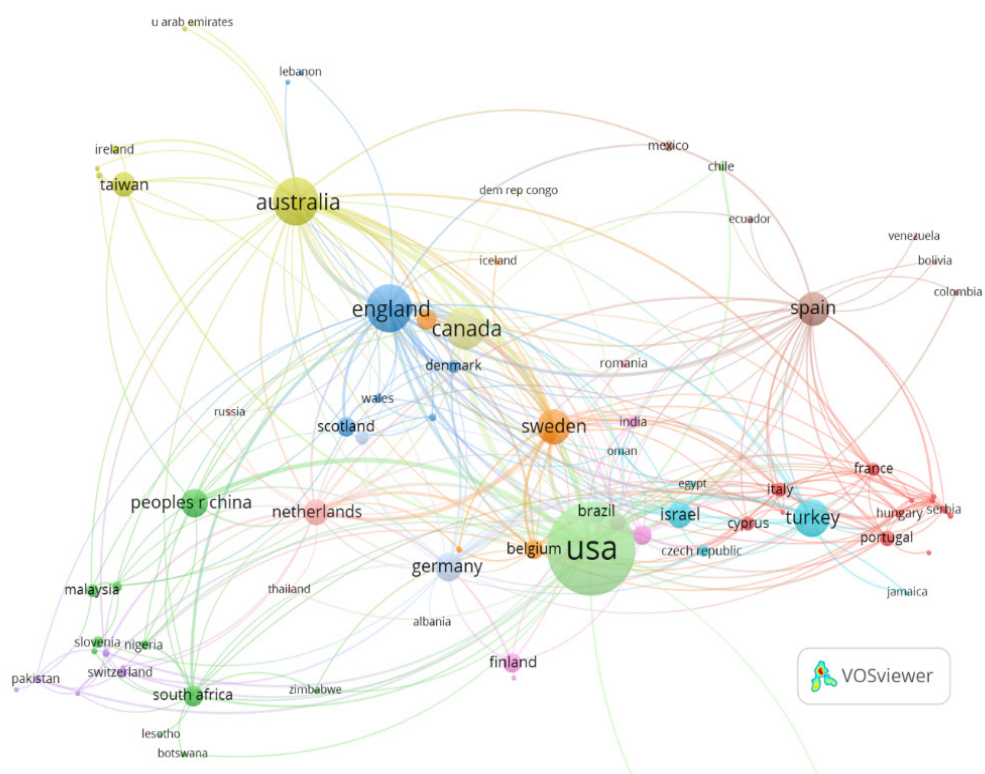
Country	*N*	%
Belgium	39	1.61
Greece	37	1.53
Finland	36	1.49
Scotland	36	1.49
South Korea	26	1.07

Considering the collaboration among countries, it is possible to divide these countries into 13 groups. The biggest group includes the United States of America, which has collaborated in E&E scientific publications with 40 countries; it is followed by England, which has collaborated with 36 countries, Australia with 34, and Spain with 31 (Figure 3). All Latin American countries are related to Spain, except Perú, which is related only to the USA. Figure 3 shows the collaboration network between countries, the size of the nodes is determined by the production on this topic per country.

Figure 3
Collaboration Network among Countries



These 2419 documents were signed by 4710 different authors, this generated 6410 signatures, because several documents were signed by more than one author, in particular, the average number of authors per article is 2.64. Also, it was found that 688 documents (28.44%) were signed by a single author, 707 (29.23%) by two authors and 485 (20.05%) by three authors. Two documents were signed by 17 authors and this is the maximum number of authors per document found. In total, 71.56% of the documents were published collaboratively.

The Degree of Collaboration (DC), which was calculated for biannual periods, shows that in the last 6 years (since 2014) the DC has achieved its maximum and it has remained constant since then (Table 5). The DC for the entire period is 0.89, this value confirms the existence of collaborative networks in scientific production in E&E.

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Table 5
Degree of Collaboration (DC) in Authorship

Period	2000-01	2002-03	2004-05	2006-07	2008-09	2010-11	2012-13	2014-15	2016-17	2018-19	Total
DC	0.87	0.81	0.74	0.81	0.80	0.88	0.88	0.92	0.92	0.92	0.89

The authors of the documents included in this analysis belong to 1233 different research institutions (every institution with at least one signatory author in one document was considered). It should be noted that in 44 documents no information about the institutional affiliation of the authors was found. Table 6 shows the universities that participate in the co-authorship of more than 20 documents. This table shows that the production is led by the University of North Carolina and followed by the University of California System. The first European university is the University of London (UK), it has 34 documents, and it is in 5th place (shared with other universities), the next European institution is Stockholm University. The first university from Oceania is the Monash University (Australia). The University of Sao Paulo (Brazil) is the first South American institution, and it has 8 documents.

Table 6
Universities with the Highest Production in Environmental Education on WoS

University	*N*	%	University	*N*	%
University of North Carolina	47	1.94	Stockholm University	24	0.99
University of California System	42	1.74	Pennsylvania State University University Park	23	0.95
Monash University	39	1.61	University of Gothenburg	22	0.91
State University System of Florida	37	1.53	University of Minnesota System	22	0.91
Pennsylvania Commonwealth System of Higher Education Pcshe	34	1.41	Middle East Technical University	21	0.87
California State University System	34	1.41	Purdue University	21	0.87
University of London	34	1.41	Purdue University System	21	0.87
Cornell University	30	1.24	University of Wisconsin System	21	0.87
University System of Georgia	30	1.24	Clemson University	20	0.83
Deakin University	27	1.12	University of Florida	20	0.83
Pennsylvania State University	27	1.12	University of Washington	20	0.83
Virginia Polytechnic Institute State University	24	0.99			

The authors provided 4719 descriptors and the descriptors assigned by WoS (based on the titles of the cited references - *Keywords plus*) were 2624. Figures 4 and 5 show the co-occurrence among the descriptors (the greater the co-occurrence, the bigger the size of the circles and the labels). The words in English were used, in order to facilitate interconnections and to avoid the possible noise due to the different denominations and languages, this is recommended in various bibliometric studies (Pinto et al., 2015).

The co-occurrence maps generated for each set of descriptors differ in the word with the greatest accumulation of density, in the authors' descriptors (figure 4) the map is denser around "environment education" while in the *Keywords plus* (figure 5) the greatest density is around "education". Considering *Keywords plus* are more objective than those provided by the authors, the research focus was their analysis.

Figures 4 and 5 shows respectively, a 2D view of the original 3D co-occurrence map of authors' descriptors and 3D co-occurrence map of descriptors *Keywords plus* assigned by *WoS*. The different nodes represent the different descriptors, and their size is determined by the frequency of apparition of each descriptor. The lines link each descriptor with the other keywords that appear with it (co-appear).

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Figure 4
Co-occurrence Map of Authors' Descriptors

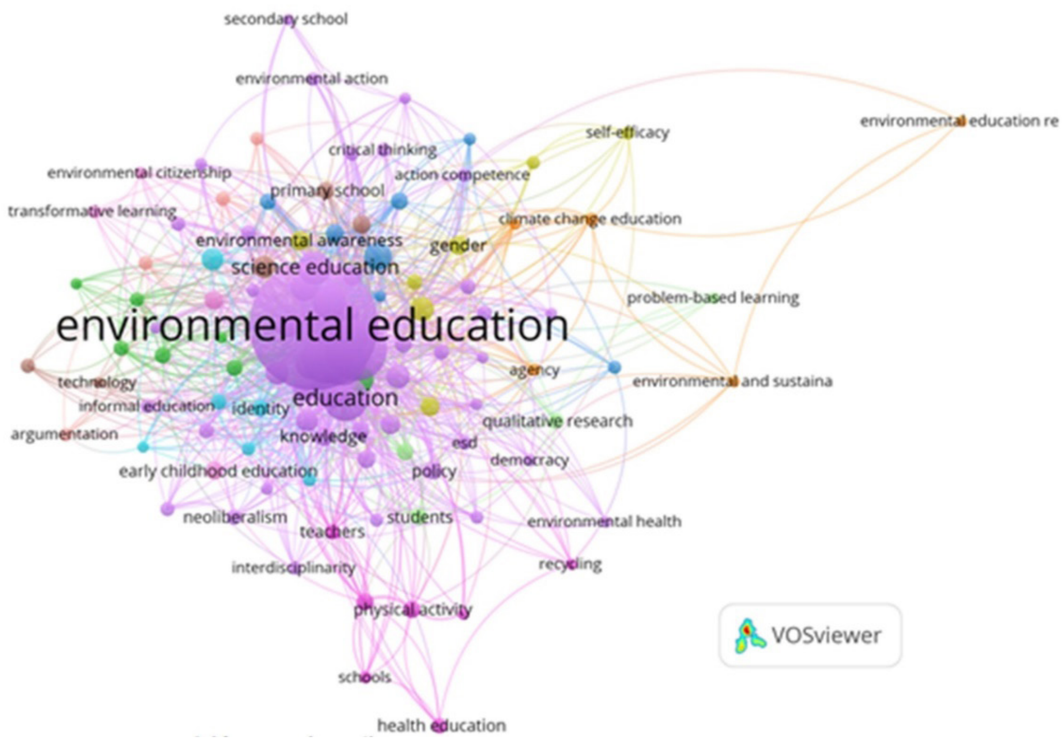
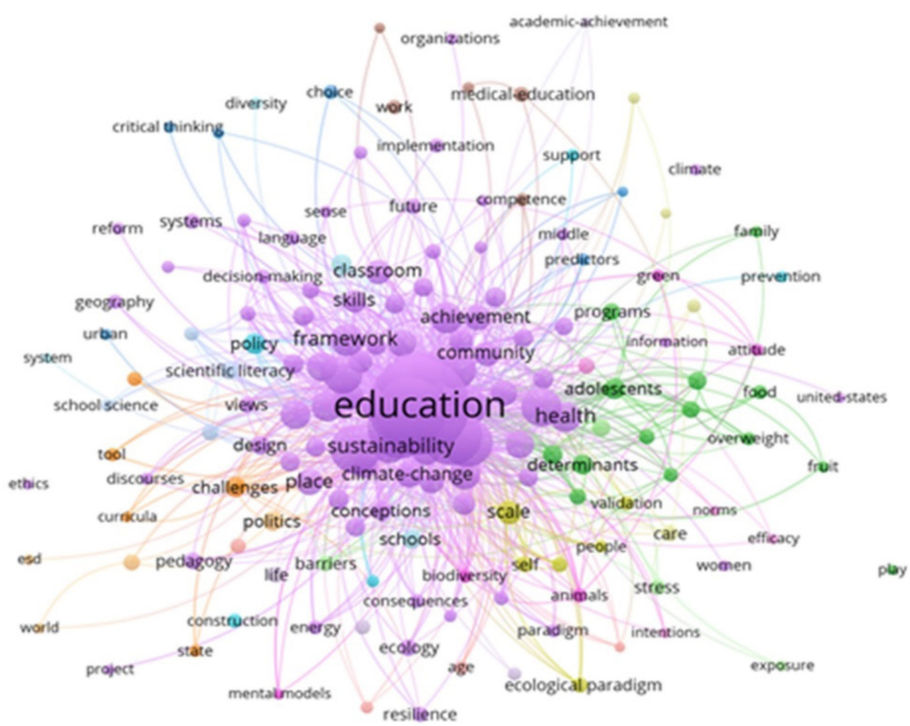


Figure 5
Co-occurrence Map of Descriptors Keywords Plus Assigned by WoS



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Descriptors whose frequency is higher than a thousand are "Education" which appears in 71.4% of all documents, and "Knowledge" in 54.6%, they both appear in more than half of the publications (Table 7). Although the descriptor "knowledge" is not recognizable in the 2D view figure, it would be recognizable on the 3D original map.

The first descriptor of environment or environmental education is "Environmental-education" which appears in 19.65% of documents and then "sustainability" in 12.4%.

Table 7
Most Frequent Keywords in Environmental Education and Education

Keyword	*N*	%	Keyword	*N*	%
Education	1726	71.4	Beliefs	346	14.1
Knowledge	1321	54.6	Higher-education	342	13.0
Science	974	40.3	Values	314	12.7
Attitudes	955	39.5	Teachers	308	12.6
Students	917	37.9	Health	305	12.4
Behaviour	687	28.4	Framework	299	12.4
Model	514	21.2	Sustainability	299	12.2
Perceptions	514	21.2	Curriculum	295	11.7
Impact	475	19.6	Achievement	284	11.5
Children	474	19.6	Literacy	277	11.2
Environmental-education	474	19.6	Management	272	10.9
School	361	14.9	Experiences	264	10.9
Performance	350	14.5	Science-education	264	14.1

In order to know more about the descriptors directly related to the environment, the keywords plus obtained in our data have been filtered using a truncation on the right side with the word "environment *". By doing so, 226 descriptors were obtained. Most of them, 69.75%, are included in less than 5 documents. Table 8 shows those that are included in 10 or more documents.

Table 8
Terms that Incorporate "Environment" 10 Times or More

Terms	Frequency	%
Environmental education	429	17.73
Environmental literacy	37	1.53
Environmental attitudes	33	1.36
Environmental awareness	19	0.79
Environmental knowledge	18	0.74
Environmental sustainability	18	0.74
Environmental behaviour	17	0.70
Environmental science	12	0.50
Pro-environmental behaviour	12	0.50
Environmental action	12	0.50
Pro-environmental behaviour	11	0.45
Environmental issues	10	0.41

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Additionally, a co-occurrence map of these filtered descriptors was created (Figure 6) and in order to have a more concrete view of these in the analysed documents, they were grouped by clusters of at least 6 elements. Table 9 presents the descriptors grouped into 11 clusters and the main topics that made the formation of clusters possible. These topics were inferred from the analysis of the different clusters.

Figure 6
Co-occurrence Map of the Descriptors Related to "Environment"

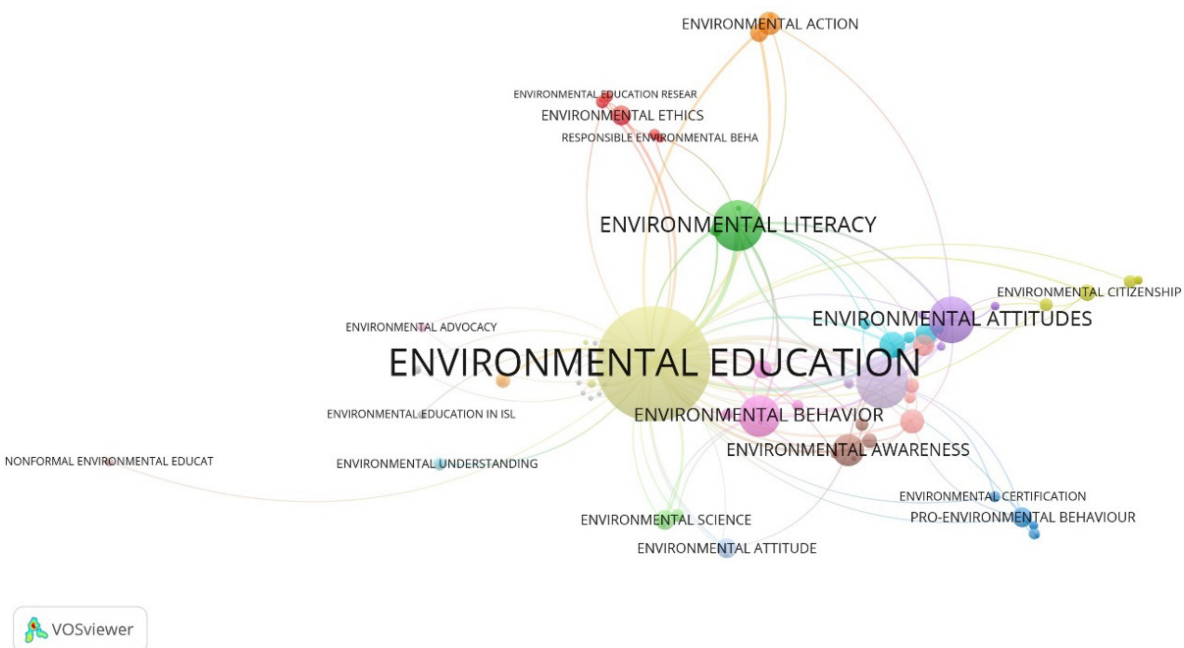

Table 9
Clusters of at Least 6 Elements for the Descriptors that Include Environment

Clusters	Descriptors	Main topics
Cluster 1 (9 items)	Environment, environment protection, environmental, environmental attitude scale, environmental awareness, environmental consciousness, environmental education curriculum, non-formal environmental education, youth environmental volunteers.	Contexts of Environmental Education -where it is applied
Cluster 2 (8 items)	Environmental concern, environmental health, environmental identity, environmental optimism, environmental racism, environmental sustainability, pro-environmental behaviours, school environment.	Environmental Education and alternative perspectives -different ways of thinking about the environment
Cluster 3 (8 items)	Environmental behaviours, environmental citizenship, environmental leadership, environmental responsibility, environmental views, multicultural environmental projects, private-sphere environmentalism, socio-environmental projects.	Projects about Environmental Education –as main strategy-
Cluster 4 (8 items)	Built environments, environmental activism, environmental certification, environmental learning, environmental service learning, experimental environmental education, integrated environmental teaching, pro-environmental behaviour.	Didactic approaches in Environmental Education -teaching, learning and evaluation
Cluster 5 (8 items)	Environmental behaviour, environmental concerns, environmental motivation, Environmental values, experiential environmental education, model of responsible environmental behaviour, pro environmental behaviours, pro environmental behaviour.	Attitudinal issues: beliefs, values, responsibility.
Cluster 6 (7 items)	Children's environmental attitudes and knowledge scale, environmental attitudes, environmental education evaluation, environmental worldview, environmentally friendly behaviours, environmentally responsible behaviour types, sponsored environmental campaign.	Affective and emotional connection with the environment.

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Clusters	Descriptors	Main topics
Cluster 7 (7 items)	Environment defined, environmental attitudes and values, environmental competences, environmental insight, environmental literacy, environmental management systems, environmentally responsible behaviour.	Components of environmental literacy.
Cluster 8 (7 items)	Environmental campaign, environmental curriculum, environmental information, environmental knowledge, environmental surveys, environmental values and attitudes, pro-environmental behaviour.	Knowledge and attitudes in Environmental Education.
Cluster 9 (7 items)	Brazilian environmental education, environmental aesthetics, environmental and sustainability education, environmental education and scientific conferences, environmental education research, postgraduate environmental education, scientific production on environmental education.	Spreading of knowledge in Environmental Education
Cluster 10 (7 items)	Constructivist learning environments, critical environmental education, environmental action, environmental interconnectedness, environmental issues, responsible environmental behaviour, urban & built environments.	Teaching approaches in Environmental Education and sustainability.
Cluster 11 (6 items)	Environmental management, environmental research, environmental science, environmental studies, environmental workshop, university environmental awareness.	Research Exercises in Environmental Education.

Discussion

Firstly, the research highlights that Environmental Education has become more popular over recent years and it has been a focus of interest in the production of knowledge, from both educational (curricular and didactic) and research fields. This interest is reflected in the increase in the production of scientific articles, especially between 2009 and 2014 and between 2017 and 2020. These results are consistent with other studies on Environmental Education (Prosser Bravo & Romo-Medina, 2019), climate literacy (García Vinuesa & Meira Cartea, 2019) or sustainability (Côrtes & Rodrigues, 2016; Hallinger & Chatpinyakoop, 2019).

This academic production occurs mainly in the form of articles (92.02%) published frequently in journals about Environmental Education, although some journals belong to other areas like: Social Sciences, Experimental Sciences, Mathematics and Technology, or Health (nursing or medicine).

The reasons why these journals, which belong to areas of knowledge not traditionally related to Environmental Education, include articles about Environmental Education are diverse; future analyses could study the relationship between Environmental Education and other topics.

Furthermore, the results obtained show that most documents are written in English (96.73%) and they come mainly from countries such as the United States of America, Australia, the United Kingdom and Canada. This reveals Anglo-Saxon's hegemony in discourses in WoS and the smaller presence of other research contexts like Latin America.

Among the most productive countries from Latin America are included three countries: Brazil, Mexico, and Colombia. According to Medina and Páramo (2014), the number of articles about E&E indexed in SSCI database by these three countries is just slightly lower than the number of articles on Environmental Education from Latin America published in journals of education indexed in SCIELO and Redalyc from 2000 to 2013.

Regarding authorship, it is noteworthy that most documents, which were published in the last two decades, are written by two or more authors/researchers, this implies that these articles are the result of a collaborative research process and writing. Many studies consider that articles written by more than one author increase their impact, for example, Borsuk et al. (2009). The results show an increase in the production in WoS and an increasing DC over recent years (0.92 between 2018 and 2019), so this collaboration could be an academic strategy to significantly increase the number of publications. Therefore, it could be considered that the presence of academic networks favoured the publication on WoS.

In addition, the degree of collaboration in E&E is 0.89, it is considerably higher than in other disciplines, for example in Psychology (0.53) (Zafrunnisha & Pullareddy, 2009), Economics (0.58) (Biradar & Tadasad, 2016) or Demography (0.6) (Maz-Machado & Jiménez-Fanjul, 2018). The reasons behind this could be diverse, among them, it could be considered the inter and transdisciplinary approach that is necessary to study and research environmental topics or problems.

Figure 3 shows important publication nodes for example in the United States of America, the United Kingdom, Australia, Canada, and Sweden. Likewise, considering the relation between Spain and some Latin American countries, connections between research contexts can be seen, this might be a strategy to promote studies about countries with less visibility, through international projects and cooperation, and also a way to promote a permanent exchange of information.

An important contribution of this study are the connections among descriptors because they could be useful for

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researchers in the area. In particular, they show how the descriptors connect Environmental Education with other aspects that have traditionally been areas of interest, reflection, and research. Also, this study shows a certain independence of Environmental Education from sustainability or sustainable development, which used to be a dominant line that could sometimes be a bit unifying and restrictive. In other words, this literature review shows studies related to this topic, but it also reveals other theoretical and methodological perspectives that are not necessarily related to sustainability.

On the other hand, the analysis of the clusters allows understanding connections or similarities between the descriptors. Therefore, 11 clusters were generated with a reduced number of elements (between 6 and 9 descriptors), in which coherent relationships (theoretical and practical) were identified. The difference in the size of the clusters is due to the different variables analysed and the similarity in the terms that are part of each one. This allowed inferring the main topics that made the formation of clusters possible (Table 9). This distribution shows that there are some latent issues in all the topics, like environmental attitudes, research in Environmental Education, teaching and learning approaches (from multiple denominations and perspectives). In addition, it shows that Environmental Education is a research field at all educational levels, even, in the training of teachers and of other professionals. Also, Environmental Education binds and integrates different types of knowledge.

This is linked to the co-occurrence of descriptors shown in Figure 6. They reveal important lines of research or problematic dimensions. Firstly, attitudinal aspects are studied from environmental psychology and sociology because there is an interest in describing the main factors in behaviours and attitudes. These issues were also mentioned by Guérin et al. (2001) and Cottrell (2003). Some studies focus on the description of scales (as part of experimental or quasi-experimental quantitative research), which are later used to analyse pro-environmental behaviours, for example Dunlap (2008) or Reyna et al. (2017). Likewise, other studies consider the relevance of learning transdisciplinary knowledge in order to explain relevant environmental situations and problems. This topic was first considered one of the foundations of scientific literacy, and now it has its own conceptual entity, environmental literacy (Lewinsohn et al., 2015; Lloyd-Strovas et al., 2018; Pe'er et al., 2007; Pitman & Daniels, 2016; Roth, 2000).

This bibliometric analysis confirmed that the problems and research topics on Environmental Education are relevant, globally extended, and characterized by a plurality of approaches, both conceptually and methodologically. Therefore, it is needed more knowledge about this field that allows researchers to understand the different behaviour among research lines on Environmental Education, to identify the problems that can be incorporated into this research field and to recognize the natural challenges of researchers when they want to extend their collaboration networks and they want to publish their results in journals included on WoS.

Conclusions and Implications

Since 2000 scientific literature on Environmental Education has experienced an important international increase. Therefore, this shows the relevance of reflection, research, policies and strategies that have been put into practice to transmit to the educational field the need to know and protect the environment. Focusing on the production on E&E, European countries publish 38.1% of the scientific production and the United States of America 33.6%, that is, 71.6% of the production on E&E comes from Europe and the USA.

North American universities are the main producers of international research in Environmental Education, and, on the opposite, Latin American universities produce collectively just 2% of the total documents analysed. The low presence of articles from Latin American countries, Asia or Africa suggests the need for different measures (political, scientific, etc.) in order to favour the democratization of knowledge.

The study that has been presented shows just a sample of the most relevant scientific production in Environmental Education, and it reveals the need for more bibliometric studies in this field in different databases; this will allow collecting more information, in order to contrast and know better the situation of this area of knowledge.

In this sense, this study allows recognizing that Environmental Education is an emerging area which interests researchers from different areas of knowledge and is enriched through collaboration (between research groups, universities, and researchers). In this regard, the study suggests the relevance of the consolidation of research networks in Environmental Education. Also, the study highlights the main topics of research in the field and the latent issues in all the topics, which will help to consolidate the theoretical and methodological identity of this discipline.

Among the limitations of this study is the difficulty of finding all the scientific production on Environmental Education because it is not a clearly delimited discipline in WoS. Due to that fact, it is possible that some related documents included in other WoS categories have not been considered in this analysis. However, the choice of the two categories *Education and Educational Research* and *Education, Scientific Disciplines* guarantees that all documents correspond to the subject under study.

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Because of this, the results offer a perspective of the scientific production related to Environmental Education, which can be contrasted with other studies that include the analysis on other databases (like Scopus, ERIC, etc.) or which study other variables or relationships, for example: academic production and the number of inhabitants per country; comparison of productivity between different areas; analysis of different types of documents such as books, book chapters, management reports of environmental corporations and Non-Governmental Organizations. Likewise, future studies can address the specific situation of a country, for example the significant increase in Turkish production in this area. Finally, it would be relevant to carry out a content analysis of the documents, which would expand our knowledge of the data obtained through this bibliometric analysis.

References

Abraham, M. F., De Lorenzo, M. S., & Haramboure, M. S. (2015). *Psicología ambiental y sustentabilidad. Análisis bibliométrico de las publicaciones en bases de datos de libre acceso* [Environmental psychology and sustainability. Bibliometric analysis of publications in open access databases]. Universidad Nacional de Mar del Plata, Argentina.

Biradar, N., & Tadasad, P. G. (2016). Authorship pattern and collaborative research in economics. *Pearl: A Journal of Library and Information Science*, *10*(1), 45-51. https://doi.org/10.5958/0975-6922.2016.00006.1

Borsuk, R. M., Budden, A. E., Leimu, R., Aarssen, L. W., & Lortie, C. J. (2009). The Influence of author gender, national language, and number of authors on citation rate in Ecology. *The Open Ecology Journal*, *2*(1), 25–28. https://doi.org/10.2174/1874213000902010025

Côrtes, P. L., & Rodrigues, R. (2016). A bibliometric study on "education for sustainability." *Brazilian Journal of Science and Technology*, *3*(1), Article 8. https://doi.org/10.1186/s40552-016-0016-5

Cottrell, S. P. (2003). Influence of sociodemographics and environmental attitudes on general responsible environmental behavior among recreational boaters. *Environment and Behavior*, *35*(3), 347–375. https://doi.org/10.1177/0013916503035003003

Dunlap, R. E. (2008). The new environmental paradigm scale: From marginality to worldwide use. *The Journal of Environmental Education*, *40*(1), 3–18. https://doi.org/10.3200/JOEE.40.1.3-18

García Vinuesa, A., & Meira Cartea, P. Á. (2019). Caracterización de la investigación educativa sobre el cambio climático y los estudiantes de educación secundaria [Characterization of educational research on climate change and secondary school students]. *Revista Mexicana de Investigación Educativa*, *24*(81), 507–535.

González-Alcaide, G., Salinas, A., & Ramos, J. M. (2018). Scientometrics analysis of research activity and collaboration patterns in Chagas cardiomyopathy. *PLOS Neglected Tropical Diseases*, *12*(6), Article e0006602. https://doi.org/10.1371/journal.pntd.0006602

González, E. J., & Puente, J. C. (2010). El campo de la educación ambiental en la región latinoamericana. Rasgos, retos y riesgos [The field of environmental education in Latin American region. Features, challenges, and risks]. *Trayectorias. Revista de Ciencias Sociales*, *12*(31), 91–106. https://www.redalyc.org/articulo.oa?id=60717342006

Guerin, D., Crete, J., & Mercier, J. (2001). A multilevel analysis of the determinants of recycling Behavior in the European Countries. *Social Science Research*, *30*(2), 195–218. https://doi.org/10.1006/ssre.2000.0694

Guimaraes, R. (1992). El discreto encanto de la Cumbre de la Tierra: Una evaluación impresionista de la Conferencia de Rio [The discreet charm of the Earth Summit: An impressionist assessment of the Rio Conference]. *Nueva Sociedad*, *122*, 86–103.

Hallinger, P., & Chatpinyakoop, C. (2019). A bibliometric review of research on higher education for sustainable development, 1998–2018. *Sustainability*, *11*(8), Article 2401. https://doi.org/10.3390/su11082401

Lewinsohn, T. M., Attayde, J. L., Fonseca, C. R., Ganade, G., Jorge, L. R., Kollmann, J., Overbeck, G. E., Prado, P. I., Pillar, V. D., Popp, D., da Rocha, P. L. B., Silva, W. R., Spiekermann, A., & Weisser, W. W. (2015). Ecological literacy and beyond: Problem-based learning for future professionals. *AMBIO*, *44*(2), 154–162. https://doi.org/10.1007/s13280-014-0539-2

Lloyd-Strovas, J., Moseley, C., & Arsuffi, T. (2018). Environmental literacy of undergraduate college students: Development of the environmental literacy instrument (ELI). *School Science and Mathematics*, *118*(3–4), 84–92. https://doi.org/10.1111/ssm.12266

Mangan, R. (2019). *Web of Science: Manual de uso [Web of Science: User manual]*. Clarivate Analytics.

Maz-Machado, A., & Jiménez-Fanjul, N. (2018). Collaboration and citation analysis within social sciences: A comparative analysis between two fields. In *Scientometrics* (pp. 65-82*)*. InTech. https://doi.org/10.5772/intechopen.76732

Maz-Machado, A., Jiménez-Fanjul, N., & Madrid, M. J. (2015). Collaboration in the Iberoamerican Journals in the category Information Science & Library Science in WOS. *Library Philosophy and Practice*, Article 1270. https://digitalcommons.unl.edu/libphilprac/1270/

Maz-Machado, A., Muñoz-Ñungo, B., Gutiérrez-Rubio, D., & León-Mantero, C. (2020). Patterns of authorship and scientific collaboration in education: The production of Colombia in ESCI. *Library Philosophy and Practice*, Article 4278. https://digitalcommons.unl.edu/libphilprac/4278/

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W. (1972). *The limits to growth (Vol. 381)*. London: Earth Island Limited.

Medina Arboleda, I. F., & Páramo, P. (2014). La investigación en educación ambiental en América Latina: Un análisis bibliométrico [Research in environmental education in Latin America: A bibliometric analysis]. *Revista Colombiana de Educación*, *66*, 55–72. https://doi.org/10.17227/01203916.66rce55.72

Novo, M. (2009). La educación ambiental, una genuina educación para el desarrollo sostenible [Environmental education, a genuine education for sustainable development]. *Revista de Educación*, *1*, 195–217.

Onopriienko, K., Onopriienko, V., Petrushenko, Y., & Onopriienko, I. (2021). Environmental education for youth and adults: A bibliometric analysis of research. In *E3S Web of Conferences* (Vol. 234, Article 00002). EDP Sciences. https://doi.org/10.1051/e3sconf/202123400002

Papadimitriou, F., & Kidman, G. (2012). Statistical and scientometric analysis of international research in geographical and environmental education. *International Research in Geographical and Environmental Education, 21*(1), 11–20. https://doi.org/10.1080/10382046.2012.639153

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Pe'er, S., Goldman, D., & Yavetz, B. (2007). Environmental literacy in teacher training: Attitudes, knowledge, and environmental behavior of beginning students. *The Journal of Environmental Education*, *39*(1), 45–59. https://doi.org/10.3200/JOEE.39.1.45-59

Pinto, M., Isabel Escalona, M., Pulgarín, A., & Uribe-Tirado, A. (2015). The scientific production of Ibero-American authors on information literacy (1985–2013). *Scientometrics*, *102*(2), 1555–1576. https://doi.org/10.1007/s11192-014-1498-x

Pitman, S. D., & Daniels, C. B. (2016). Quantifying ecological literacy in an adult western community: The development and application of a new assessment tool and community standard. *PLOS ONE*, *11*(3), Article e0150648. https://doi.org/10.1371/journal.pone.0150648

Prosser Bravo, G., & Romo-Medina, I. (2019). Investigación en educación ambiental con menores en Iberoamérica: Una revisión bibliométrica de 1999 a 2019 [Research in environmental education with minors in Ibero-America: A bibliometric review from 1999 to 2019]. *Revista Mexicana de Investigación Educativa*, *24*(83), 1027–1053.

Reyna, C., Bressán, E., Mola, D., Belaus, A., & Ortiz, M. V. (2017). Validez estructural de la Escala del Nuevo Paradigma Ecológico en ciudadanos argentinos utilizando diferentes abordajes [Structural validity of the New Ecological Paradigm Scale in Argentine citizens using different approaches]. *Pensamiento Psicológico*, *16*(1), 107-118. https://doi.org/10.11144/Javerianacali.PPSI16-1.vsne

Roth, E. (2000). Psicología ambiental: Interfase entre conducta y naturaleza [Environmental psychology: Interface between behavior and nature]. *Revista Ciencia y Cultura*, *8*, 63–78.

Subramanyam, K. (1983). Bibliometric studies of research collaboration: A review. *Journal of Information Science*, *6*(1), 33–38. https://doi.org/10.1177/016555158300600105

UNESCO. (1978). *Intergovernmental Conference on Environmental Education, Tbilisi, USSR, 14-26 October 1977: Final report*. UNESCO.

UNESCO. (1987). *Unesco-UNEP International Congress on Environmental Education and Training (Moscow, USSR, 17-21 August 1987)*. UNESCO.

UNESCO. (2002). *Education for sustainability: From Rio to Johannesburg: Lessons learnt from a decade of commitment*. UNESCO.

United Nations. (1973). *Report of the United Nations Conference on the Human Environment, Stockholm, 5-16 June 1972*. United Nations.

Van Eck, N. J., & Waltman, L. (2020). *VOSviewer manual 1.6.15*. Univeristeit Leiden.

Vilches Peña, A., & Gil Pérez, D. (2016). La transición a la sostenibilidad como objetivo urgente para la superación de la crisis sistémica actual [The transition to sustainability as an urgent objective to overcome the current systemic crisis]. *Revista Eureka Sobre Enseñanza y Divulgación de Las Ciencias*, *13*(2), 395–407.

World Commission on Environment and Development. (1987). *Our common future*. Oxford University Press.

Zafrunnisha, N., & Pullareddy, V. (2009). Authorship pattern and degree of collaboration in psychology. *Annals of Library and Information Studies*, *56*(4), 255–261.

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STUDENTS' CONCEPT ORGANISATION REGARDING CHEMICAL EQUILIBRIUM IN UPPER-SECONDARY EDUCATION: BASED ON REACTION TIME TECHNIQUE

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Abstract. *Chemical equilibrium is so important domain knowledge in chemistry that the corresponding organisation of concepts in students has been an interesting but unsolved issue. A deeper understanding of how students organise the relevant concepts in long-term memory is beneficial to develop more targeted teaching practices. This research utilized the reaction time technique as a new approach to exploring upper-secondary school students' organisation of concepts regarding chemical equilibrium. A category judgment task involving 247 Chinese twelfth-grade students from two upper-secondary schools was conducted. The results showed that a significant difference was between the reaction time of concept dimensions. The mean reaction time of the dimension 'reversible reaction' was the shortest, but the dimension 'representation of state' had the longest mean reaction time. Next, there was no significant difference in the organisation of concepts between students studying chemistry at different levels of academic achievement. These findings provide a new and essential picture to deeply understand the organisation of concepts regarding chemical equilibrium and help focus on the relations between some relevant concepts. This research represents that the reaction time technique can be utilized in the research on organisation of science concepts.*

Keywords: *category judgment task, chemical equilibrium, organisation of concepts, reaction time*

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Introduction

How the concepts are organised in an individual's mind is an interesting and essential research issue. Cognitive psychologists have developed theories to describe the organisation of concepts (Foster, 2009; Solso, et al., 2014) and some techniques representing different forms of the organisation in an individual's memory (Jonassen, et al., 1993). In the classical theory perspective, they have utilized the semantic network to explain the way concepts organise (Collins & Quillian, 1969; Quillian, 1968). In the semantic network, the nodes are considered as the concepts or propositions, and the links connecting them represent the order and propositional relationship (Norman, et al., 1976). Theme-relevant concepts are distributed around the target concept. Employing the assumption of the semantic network, science education researchers have explored various forms of science concept organisation in students' minds (Geeslin & Shavelson, 1975; Qian, 2008; Soika & Reiska, 2014).

Chemical equilibrium has been considered as a difficult learning topic in chemistry (Bergquist & Heikkinen, 1990; Finley, et al., 1982; Johnstone, et al., 1977). Students need to know various abstract and relevant concepts in the knowledge of chemical equilibrium. To help students more easily to learn chemical equilibrium, chemistry education researchers have focused on students' learning progress and outcome of chemical equilibrium (Akkus, et al., 2011; Barke, et al., 2009; Chiu, et al., 2002; Hackling & Garnett, 1985; Özmen, 2008).

Especially, the organisation of concepts as a learning outcome in long-term memory is the foundation of declarative knowledge, affecting conceptual understanding. Chemistry education researchers have paid attention to the organisation of concepts revealing the distribution and distance among the concepts. For example, Wilson (1994, 1996) required upper-school students to finish the concept map from some selected concepts related to chemical equilibrium. Students wrote the considered and directed connection among the relevant concepts in the concept maps

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but easily missed some connection between the relevant concepts and the concept 'chemical equilibrium'. Next, Gussarsky and Gorodetsky (1988, 1990) utilized word association surveys to acquire the most relevant concepts of chemical equilibrium in upper-secondary school students. The results only represented the concepts and their categories in the semantic network, but not represented the connection distances between the relevant concepts and the concept 'chemical equilibrium'. It was beneficial to collect students' behavioural results in a special method and show their organisation of concepts at the group level, highlighting the information concerning the distances between concepts and gaining a global perspective. Chemistry education researchers can reflect on the existing research results and promote the teaching practice of chemical equilibrium.

Furthermore, chemistry education researchers have found a close relationship between the organisation of concepts regarding chemical equilibrium and the academic level that students had (Gussarsky & Gorodetsky, 1988, 1990; Wilson, 1994, 1996). It has been unclear how the differences between the organisations of concepts acquired by the new approach form students with different levels of academic achievement in chemistry. The answer to this unsolved issue can help chemistry education researchers learn more about the relationship and identify the possible influencing factors.

Spreading Activation Theory

Based on the assumption of the semantic network, Collins and Loftus (1975) developed the spreading activation theory to explain the change of spreading activation in an individual's information retrieval. As spreading activation theory assumed, the attenuation of spreading activation is a complicated process influenced by the semantic similarity between concepts. Semantic similarity refers to the number of properties belonging to concepts. If those concepts have more common properties, they have a higher level of semantic similarity so that they are more linked closely and related internally. As a result, the distances between those concepts are shorter in the semantic network. Moreover, the frequency of concept usage also affects the strength of the links in the semantic network. A highly used relevant concept and the target concept are expected to have a higher strength of the link and a shorter distance. In brief, the number of properties, the level of semantic similarity, the strength of the links, the degree of relatedness, and the distance between concepts are interrelated.

When an individual is stimulated by the input information (such as words), the activation of the nodes and the search in the semantic network spread through the links connected to those nodes to other nodes, and the lexical processing occurs. The recognizing, recalling, and classifying all require semantic activation and search for the closest nodes as relevant concepts in the semantic network firstly. The spreading activation theory assumes that the activation of the nodes decreases with low strength of the links and long spreading distances. For example, an irrelevant concept has a long distance from the target concept. The activation of the node regarding this irrelevant concept is attenuated so that the time of spreading activation towards this node becomes long. As a result, the individual utilizes a long time to recognize, recall, or classify this irrelevant concept. In other words, the more related to the target concept a concept is, the shorter time the spread of activation has.

If the spreading time of relevant concept is measured respectively by a research approach, the distance between the relevant concept and the target concept and the degree of relatedness between them can be inferred (Collins & Loftus, 1975; Danguecan & Buchanan, 2016; Recchia & Jones, 2012). The behavioural results also can be utilized to represent a corresponding organisation of concepts that may exist in the semantic network.

Reaction Time Technique

The reaction time technique is a fundamental research approach in psychology, providing the individual's response time as a behavioural result to represent the cognitive process (Jiang, 2012; Kantowitz, et al., 2008; Solso, et al., 2014). The reaction time is the interval of time between a signal and a reaction to it when a stimulus appears in front of the participant and then the participant begins to make an act of response. The reaction time is measured by the professional software in the computer, which time is between the stimulus appears on the computer screen and then the participant presses on the button of a computer keyboard. Generally speaking, the more complex the cognitive process that the participant experiences, the longer the reaction time. Psychologists can infer the stages of the cognitive process through the reaction time of behavioural experiments.

In the research studies of science education, researchers have utilized reaction time technique to explore students' science learning. The research topics were concerning students' persistence of the naive science concept

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or intuitive reasoning on the science concept, including the research studies of matter classification (Babai & Amsterdamer, 2008), living thing classification (Babai, et al., 2010), physical phenomena (Potvin, et al., 2015), probability (Babai, et al., 2006), geometrical shape (Babai, et al., 2012), and electricity (Zhu, et al., 2019).

Various kinds of tasks elicit an individual's specific cognitive process to address different research issues. The category judgment task requires the participants to judge the relations between the concepts utilized as stimuli and a special category utilized as the target (Jiang, 2012). The essence of the task is to identify the relatedness between the tested concepts and the target concept. The more closely the tested concept is related to the target concept, the shorter the reaction time. Considering the reaction time as a function of the relative distance, the tested relevant concept is expected to have a short distance from itself to the target concept in the semantic network.

Previous research studies have employed category judgment task to collect the data for the research of semantic distance regarding the chemistry concepts in upper-secondary school students, such as the concepts 'ionic reaction' (Wang, 2018), 'redox reaction' (Tang, 2019), and 'galvanic cell' (Li, 2020). They have inferred the relative distance between the relevant concept and the target concept from the length of reaction time, but not combined all relative distances to explore and visualize the latent organisation of the concepts.

It is necessary to construct a new form of the concept organisation in which relevant concepts are distributed around the target concept according to the relative distance in the semantic network. This organisation of concepts acquired by the reaction time technique can reveal more fundamental and deeper relations between concepts than the forms acquired by other techniques, such as concept mapping. Although different forms of the concept organisation regarding chemical equilibrium have been identified (Gussarsky & Gorodetsky, 1988, 1990; Mai, et al, 2021; Wilson, 1994, 1996), there have been so few reports using reaction time technique on the learning of chemical equilibrium that chemistry education researchers had no idea what this organisation of concepts was like and what the targeted suggestions for teaching practice were. To deeply understand how the students organise the relevant concepts in long-term memory after learning and to optimize the teaching design and practice, chemistry education researchers can explore and analyse this new group level organisation of concepts held by students.

Research Questions

This research utilized the reaction time technique to explore the group level organisations of concepts regarding chemical equilibrium in upper-secondary school students studying chemistry at different levels of academic achievement. The research questions solved in this research were as follows:

(1) How long is the reaction time of the concepts related to chemical equilibrium?

(2) How are the organisations of concepts regarding chemical equilibrium?

Research Methodology

General Background

This research conducted a cognitive psychology-oriented test to explore the organisation of concepts regarding chemical equilibrium at group level, involving 247 upper-secondary school twelfth-grade students as participants in Guangzhou, China during the 2019-2020 academic year. The test utilized the reaction time technique and category judgment task to acquire the behavioural data from students with different levels of academic achievement in chemistry. The reaction time data concerning the judgement of relation between concepts were utilized to form and visualize the organisation of concepts.

Participants

Research studies on psychology using reaction time technique usually involve only a few dozen or fewer participants (Jiang, 2012). To more accurately represent the new organisation of concepts at the group level from the reaction time data, this research enlarged the sample size to acquire a large number of valid dates, taking two or three classes of students from a school as a group.

In consideration of the practical feasibility, more than two hundred Chinese twelfth-grade students (16-17 years old) studying chemistry at different levels of academic achievement were invited and participated in the test. Participants came from two upper-secondary schools in Guangzhou, China, including 148 students in three

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classes at School A and 99 students in two classes at School B. The invitation was conducted with the help of school administrators. The students agreed to accomplish the test after understanding the purpose of this research.

Students' level of academic achievement in chemistry was determined according to the result of the chemistry academic achievement test conducted by the regional education administration department. The scope of the test included the whole content of the Chinese upper-secondary school chemistry curriculum. Students at School A had an outstanding performance in the test. Their average test score was in the top 6% of all 120 upper-secondary schools and significantly higher than the average test score of all schools. Students at School B studied chemistry at an average level, whose average test score was close to the average test score of all schools, ranking 44th among all schools. Before participating in this research, the students had studied the topic of chemical equilibrium in a chemistry elective module (Song, 2007b) and known the meaning of the concepts utilized in the task.

To eliminate the data bias that occurred in the task, 49 students were excluded by the criteria (more details were shown in the Data Analysis session). The valid sample comprised 198 students (valid rate: 80.2%, average age = 16.37 ± 0.48 years, 87 males and 111 females), including 124 students from School A (Group A), and 74 students from School B (Group B).

Instrument and Procedures

In the authors' previous research (Mai, et al, 2021), 24 concepts related to chemical equilibrium were selected from Chinese upper-secondary school chemistry curriculum materials (MOE, 2003, 2018; National Education Examinations Authority, 2018; Song, 2007a, 2007b; Wang, 2007; Wang, et al., 2007; Wang, 2014a, 2014b) and rated by a large number of chemistry research and teaching practice experts. According to the relations between concepts in chemistry and advice of some experts, these concepts were divided into six dimensions (shown in Table 1), which represented different parts of learning content regarding chemical equilibrium. It is worth noticing that the concept 'feature of chemical equilibrium' is a commonly used concept in Chinese upper-secondary school chemistry teaching. Chinese chemistry teachers utilize this concept to refer to five features of chemical equilibrium, such as 'reversible', 'dynamic', and other features so that students can quickly understand diverse aspects of chemical equilibrium. Using this concept familiar to students in this research was appropriate and necessary. Moreover, in the research material development, some students similar to the participants were able to distinguish the meaning of the concepts in a small group interview. These concepts were suitable for exploring students' organisation of concepts regarding chemical equilibrium in this research.

Table 1
Twenty-four Concepts Related to Chemical Equilibrium and Its Dimensions

Dimension	Concepts
Representation of state	Limitation of chemical reaction, Establishment of the equilibrium state, Chemical equilibrium constant, Reaction quotient, Degree of conversion at equilibrium
Shift of state	Shift of equilibrium state, Le Chatelier's Principle, Direction of the shift in chemical equilibrium, Position of equilibrium moved to the right, Position of equilibrium moved to the left
Feature of equilibrium	Feature of chemical equilibrium, Dynamic equilibrium, Reversibility, Reversible process
Reversible reaction	Reversible reaction, Forward reaction, Reverse reaction
Reaction rate	Chemical reaction rate, Rate of the forward reaction, Rate of the reverse reaction
Condition	Condition, Temperature, Concentration, Pressure

The category judgment task comprised a training task on the subject of the galvanic cell including 48 training trials, and a testing task regarding chemical equilibrium including 48 formal trials. Twenty-four concepts related to the galvanic cell and 24 irrelevant concepts were utilized as test items in training trials. On the other hand, 24 concepts related to chemical equilibrium and 24 irrelevant concepts were utilized as test items in formal trials. Irrelevant concepts were of other themes regarding atomic structure, common compound, and experimental operation. Concepts regarding the galvanic cell and irrelevant concepts were all selected and rated by some chemistry

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research and teaching practice experts. The purpose of using irrelevant concepts was to focus participants' attention on their tasks. Each item was utilized in a trial without repeat.

Photographs involving those items were utilized as test materials. The background of the photograph is black, but the Chinese name of the target concept presented on the left and that of the item presented on the right are white (examples are shown in Figure 1). Item 'dynamic equilibrium' in Figure 1(a) is utilized as a relevant item when item 'nonpolar bond' in Figure 1(b) is utilized as an irrelevant item. The Chinese font size is 54 points to make participants watch the items.

Figure 1
Examples of the Photographs Presented in the Task

(a) Chemical equilibrium - Dynamic equilibrium

(b) Chemical equilibrium - Nonpolar bond

The category judgment task was conducted on a personal computer by using E-Prime 2.0. Basing on the setting procedure, E-Prime selected a photograph of an item as a stimulus in random order and presented it on the computer screen in each trial.

Participants accomplished the category judgment task individually in the computer room of the upper-secondary school. The task included three stages. First, participants were presented with instructional slides to understand the aim and process of the task. Next, in training trials, participants were required to judge whether each item presented on the computer screen was related to the target concept 'galvanic cell', and to press on different buttons as quickly and correctly as possible. If the participant judged the presented item was related to the target concept, then pressed on the 'F' button, or else pressed on the 'J' button. Presented items were divided into two categories by participant's judgment. After experiencing the training trials and familiarizing the operation, participants judged whether the presented items were related to the target concept 'chemical equilibrium' in formal trials. The whole task cost approximately 15 minutes. E-Prime measured and recorded automatically participant's response and reaction time of each trial. The procedures were conducted following the Ethical Principles for Psychologists and Code of Conduct of the American Psychological Association.

Data Analysis

Three methods of data cleaning were conducted to improve the data quality. First of all, for each participant, the reaction time of less than 300 ms was removed because the data did not result from a genuine word recognition process (Jiang, 2012). Second, based on the Pauta criterion, the reaction time more than or less than 2 *SD* from the mean of the same participant was treated as outliers and eliminated (Jiang, 2012). Third, according to the advice of Jiang (2012), Babai and Amsterdamer (2008), the participants were excluded who had a rate of accuracy of responses less than 80%, and who had less than two correct responses in trials belonging to a concept dimension. As a result, the data from 198 students were thus accepted.

Because the analysis of students' organisation of concepts regarding chemical equilibrium was the aim of

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this research, the data of correct responses in formal trials were analysed by using SPSS 23.0. First, the mean reaction time of each item and that of each concept dimension related to chemical equilibrium were calculated. Then, Two-factor repeated measure ANOVA was performed on students' reaction time of correct responses, exploring the interaction effect between the type of school and the concept dimensions. Finally, the Bonferroni method was utilized in multiple comparisons of mean reaction time of different concept dimensions.

According to spreading activation theory and the assumption held by this research, the length of reaction time for each item was considered as an indicator to represent the relative distance between the corresponding relevant concept and the concept 'chemical equilibrium'. The reaction time of all items was combined to form the students' visual organisation of concepts in the radar chart.

Research Results

The Accuracy of Category Judgment Responses

Although the rates of correct classification for two groups of students were high (M_A = 91.87%, SD_A = 4.08; M_B = 89.64%, SD_B = 4.04), a significant difference was found in the rate between Groups A and B [t = 3.736, p < .001, Cohen's d = 0.549 (medium effect)]. Group A had a significantly better performance than Group B in judging the items related to chemical equilibrium.

The Reaction Time of Category Judgment Responses

Table 2 shows the mean reaction time of six concept dimensions. They were listed in descending order as below: Representation of state > condition > feature of equilibrium > shift of state > reaction rate > reversible reaction.

Table 2
Reaction Time (ms) of Six Concept Dimensions

Dimension	*M*	*SE*	Multiple comparisons
1. Representation of state	1167.05	398.66	1 > 2; 1, 2, 3, 6 > 4; 1, 3, 6 > 5
2. Shift of state	1013.75	323.68	
3. Feature of equilibrium	1073.32	390.41	
4. Reversible reaction	929.87	305.72	
5. Reaction rate	960.34	345.14	
6. Condition	1080.56	363.46	

There was no interaction effect between the type of school and the concept dimensions [F = 0.991, p = .419]. Only a significantly main effect of the concept dimensions was found [F = 17.944, p < .001, η_p^2 = 0.084 (medium effect)]. The results of multiple comparisons are shown in Table 2. First, the mean reaction time of the dimension 'reversible reaction' was significantly shorter than those of the other four dimensions (p < .05). Moreover, the mean reaction time of the dimension 'representation of state', 'feature of equilibrium', and 'condition' was significantly longer than that of the dimension 'reaction rate' (p < .01), respectively. Furthermore, a significantly longer mean reaction time was found for the dimension 'representation of state' than for the dimension 'shift of state' (p < .001).

The mean reaction time of the items in Groups A and B is listed in Table 3. Basing on the results, the item 'reaction quotient' had the longest mean reaction time in Groups A and B (1354.58 ms and 1276.14 ms respectively). Oppositely, the mean reaction time of the item 'reverse reaction' in Group A (828.33 ms) and that of the item 'rate of the forward reaction' in Group B (878.19 ms) was the shortest, respectively.

On the other hand, the mean reaction time of quite a few items in Groups A and B was not consistent. For example, except for the items 'Le Chatelier's Principle' and 'reversible process', the mean reaction time of other items belonging to the dimensions 'representation of state', 'shift of state' and 'feature of equilibrium' in Group A, was longer than those in Group B.

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Table 3
Reaction Time (ms) of the Items in Groups A and B

Dimension	Item	Group A		Group B	
		M	*SD*	*M*	*SD*
Representation of state	Establishment of the equilibrium state	1194.05	675.19	1147.97	601.53
	Limitation of chemical reaction	1307.37	672.74	1143.00	453.80
	Chemical equilibrium constant	999.41	496.11	944.43	492.47
	Reaction quotient	1354.58	716.73	1276.14	542.23
	Degree of conversion at equilibrium	1180.68	826.07	1041.57	458.15
Shift of state	Shift of equilibrium state	1015.18	492.17	982.41	534.19
	Le Chatelier's Principle	985.83	384.66	1132.19	339.41
	Direction of the shift in chemical equilibrium	1047.44	582.20	947.06	461.93
	Position of equilibrium moved to the right	1018.84	792.58	932.33	493.16
	Position of equilibrium moved to the left	1110.63	726.99	934.50	368.56
Feature of equilibrium	Feature of chemical equilibrium	1318.76	922.73	1199.46	605.62
	Dynamic equilibrium	1090.69	614.21	980.46	450.33
	Reversibility	1057.84	558.78	976.11	427.33
	Reversible process	921.54	484.94	986.85	526.27
Reversible reaction	Reversible reaction	972.92	655.41	912.29	491.95
	Forward reaction	950.26	496.21	987.37	545.87
	Reverse reaction	828.33	311.94	925.31	405.33
Reaction rate	Chemical reaction rate	944.71	447.93	957.26	539.36
	Rate of the forward reaction	1037.29	680.60	878.19	362.53
	Rate of the reverse reaction	933.61	399.12	993.07	441.72
Condition	Condition	1121.70	622.72	1085.93	526.38
	Temperature	1004.39	456.17	1060.92	436.02
	Concentration	1134.49	875.81	1034.95	592.17
	Pressure	1076.89	552.40	1221.58	442.68

The Organisation of Concepts

In Figure 2, the centre of the circle in the radar chart is regarded as the target concept 'chemical equilibrium'. The distance between two adjacent circles represents the reaction time of 200 ms and the excircle thus represents the reaction time of 1400 ms. The dots representing the items of six dimensions are distributed over six different parts of the circle. The positions of those dots are determined by the mean reaction time of their corresponding items. Therefore, Figure 2 represents the organisations of concepts from Groups A and B in the semantic network.

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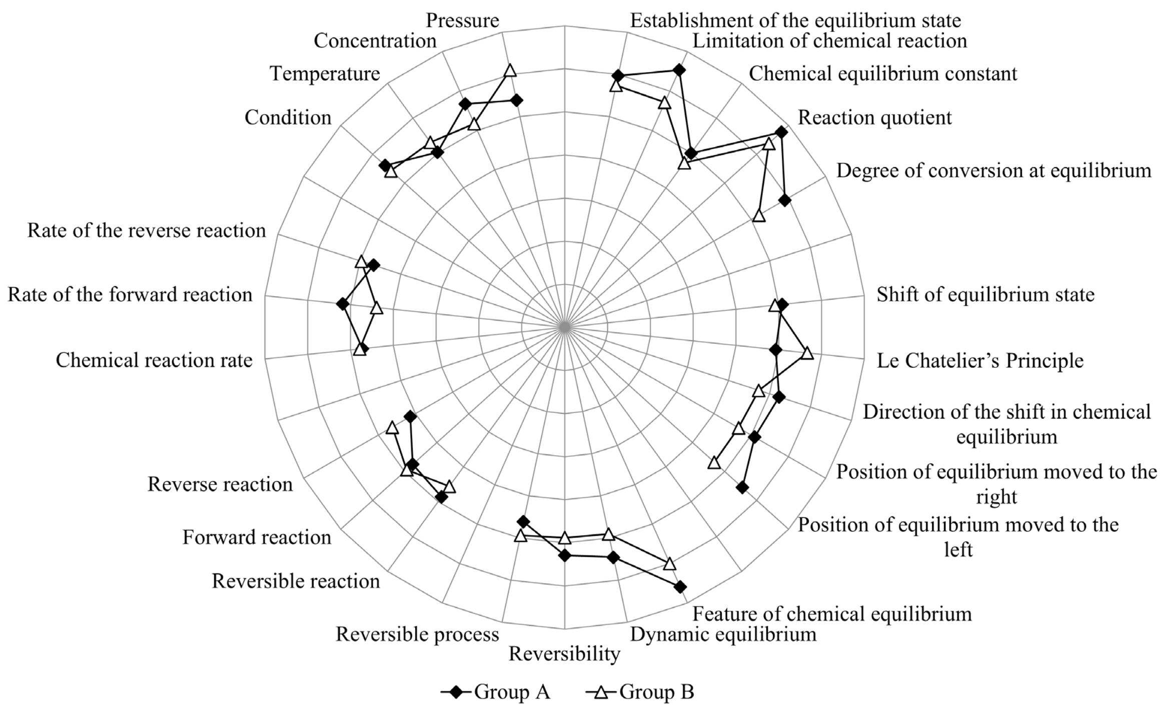
Figure 2
Radar Chart Representing the Organisations of Concepts Regarding Chemical Equilibrium



Note: The scale indicates 200 ms.

As shown in Figure 2, comparing to the dots of the items belonging to other dimensions, the dots of the items belonging to the dimensions 'reaction rate' and 'reversible reaction' are closer to the centre of the circle. Next, although the concept 'reaction quotient' is essential to identify the state of chemical equilibrium, its corresponding dot is far from the centre of the circle.

Moreover, by comparison with Group A, the dots of the items belonging to the dimensions 'representation of state', 'shift of state', and 'feature of equilibrium' in Group B are closer to the centre of the circle. For most dots of the items, the distance from the dot to the centre of the circle is different between the two groups. In brief, the organisations of concepts from two groups of students were inconsistent. However, because the main effect of the type of school was not found in this research, the difference in the organisations of concepts between the two groups of students was not significant.

Discussion

This research employed the category judgment task to acquire the reaction time from upper-secondary school students, revealing the new organisation of concepts regarding chemical equilibrium at the group level. Reaction time was utilized as a relative distance to indicate how close the relevant concepts were to the concept 'chemical equilibrium' in the semantic network, and how the organisation of concepts was. Four parts of the results were discussed as follows.

The Accuracy of Responses

First, the accuracy of responses from students was discussed. The concepts related to chemical equilibrium were rated by chemistry research and teaching practice experts, who could judge the knowledge space of chemical equilibrium (Mai, et al, 2021). In this research, the students studying chemistry at an outstanding

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level of academic achievement might more deeply understand the relations between the relevant concepts and the concept 'chemical equilibrium' and have a wider knowledge space than other students with a lower level of academic achievement in chemistry. As a result, if students held more knowledge space with the experts, they could judge so much more correct concepts into the relevant category that they accomplished a higher accuracy of responses.

Similarly, in the limit-time free word association test, Gussarsky and Gorodetsky (1990) also found that the number of concepts written by Israeli upper-secondary school students with the basic level of academic achievement in chemistry was smaller than that written by the students studying chemistry at a higher level of academic achievement. These results of the accurate responses were consistent with the researchers' expectations.

The Reaction Time of the Dimensions

The second discussion was on the subject of the dimensions with short reaction time. For all students participating in this research, the mean reaction time of the dimension 'reversible reaction' was the shortest in all dimensions, and that of the dimension 'reaction rate' was the second. It suggested that the concepts of the dimensions 'reversible reaction' and 'reaction rate' were significantly closer to the concept 'chemical equilibrium' than other concepts in the semantic network. It was also proposed that the distances from the concepts of different dimensions to the target concept were different.

Because the relevant concepts stored in the semantic network were the learning outcome, the above findings could be explained from the perspective of chemistry teaching practice. Although the chemical reaction rate is the essential content of chemical kinetics and chemical equilibrium is belonging to the core content of chemical thermodynamic, they are in close relation in chemistry. In fact, at the beginning of the chapter on chemical equilibrium, Chinese upper-secondary school chemistry textbooks introduce the concept 'chemical equilibrium' by discussing the change combining the rate of the forward reaction and that of the reverse reaction (Song, 2007a, 2007b; Wang, 2014a, 2014b). Moreover, chemistry teacher requires students to analyse diverse kinds of 'chemical reaction rate – reaction process' graph, discussing how chemical equilibrium establishes and shifts when the rate of reversible reaction changes in various reaction situations (Huang, et al., 2018; Liu, et al., 2017). It is easy for students to establish a high strength of the links among reversible reaction, the rate of a reversible reaction, and chemical equilibrium. Therefore, comparing to the concepts of other dimensions, the concepts of the dimensions 'reversible reaction' and 'reaction rate' can have higher frequencies of usage, so that they can appear more closely to the concept 'chemical equilibrium' in the organisation of concepts. As a result, when students saw those concepts as stimuli respectively, they could give a faster semantic activation and response. It made the reaction time of those corresponding items shorter.

Previous research studies have shown that students easily confused and conflated the concepts of chemical thermodynamics with those of chemical kinetics in the learning of chemical equilibrium (Bain & Towns, 2016; Van Driel, 2002). The finding in this research can provide evidence of structural knowledge to reveal the latent and discrete distributive relations involving these misapprehended concepts. The result helps researchers study the semantic understanding of these concepts in the future.

The Reaction Time of the Relevant Concepts

The third discussion focused on some items with long reaction time. The concepts 'reaction quotient' and 'feature of chemical equilibrium' are related to chemical equilibrium. In the teaching practice of chemical equilibrium, the chemistry teacher guides the students to compare the value of the reaction quotient to the value of the chemical equilibrium constant, in order to judge the shift direction of chemical equilibrium, and to interpret and exemplify the features of chemical equilibrium (Huang, et al., 2018; Song & Wang, 2016). In the research material development, some students in a small group interview could state the meaning of those concepts and agree to the significance of those concepts in the learning of chemical equilibrium. The mean reaction time of the items corresponding to those concepts was expected to be shorter than those of other items, but the result was the opposite of the authors' hypothesis. It revealed that those concepts might have long distances to the concept 'chemical equilibrium' in the semantic network, respectively.

The calculations involving reaction quotient and other quantitative processes regarding chemical equilibrium bring students the learning difficulties and varieties of misconceptions (Huddle & Pillay, 1996; Kousathana

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& Tsaparlis, 2002; Ollino, et al., 2018). The authors assumed that students might focus on the process of problem-solving but not put more attention to the names of those concepts. Compared to other concepts, it thus made lower frequencies of those two concepts usage in student's learning experience. A longer reaction time occurred when students saw the stimuli regarding those two concepts. In addition, more evidence is needed for researchers to deeply explore this finding in the future.

The Organisation of Concepts

The fourth discussion was on the subject of the organisation of concepts for students. Comparing to different forms of the concept organisation (Gussarsky & Gorodetsky, 1988, 1990; Mai, et al, 2021; Wilson, 1994, 1996), the new form identified in this research did not provide the proposition networks or the categories of concepts but afforded the whole picture of all relevant concepts distribution according to the relative distance of each relevant concept in the latent semantic network.

Table 3 and Figure 2 depict and visualise the inconsistent and diverse organisations of concepts for students with different levels of academic achievement in chemistry. The authors assumed that two groups of students not only differed in the reaction time of the relevant concepts but also differed in the semantic activation and the degree of relatedness towards the relevant concepts, even in the frequencies of concept usage in formal learning.

Although students might differ in many aspects of the cognitive process regarding chemical equilibrium, students did not significantly differ in the organisation of concepts at the group level. In other words, students with different levels of academic achievement in chemistry constructed an organisation of concepts having no significant difference in long-term memory, respectively. It was probably because students perceived and understood the basic relations between concepts in chemistry teaching practice so that they could construct a similar organisation of concepts.

The organisation of concepts plays an essential role in concept understanding and problem-solving (Foster, 2009; Jonassen, et al., 1993; Solso, et al., 2014). The identified organisation of concepts provides the information about which relevant concept has a longer relative distance to the target concept and reminds chemistry teachers to pay attention to the teaching process and the interpretation of that concept. For example, chemistry teachers in both two groups can reflect on the teaching of the concepts 'reaction quotient' and 'feature of chemical equilibrium', while chemistry teachers in Group B noticing to explain the concept 'limitation of chemical reaction' in more depth.

Furthermore, the reaction time technique utilized in this research only produced the distances between the relevant concepts and the target concept. It did not produce the relative distances and the direct connection among the relevant concepts. The organisations of concepts representing in Figure 2 are incomplete and expected to be more complex. Therefore, the whole organisation of concepts will be acquired with the aid of additional techniques and tasks in the future.

Conclusions and Implications

Basing on spreading activation theory, this research explored the organisation of concepts regarding chemical equilibrium in upper-secondary school students by using the reaction time technique. The new and essential picture of the organisation of concepts was represented and analysed. The results showed that a significant difference between the reaction time of concept dimensions was found. Next, students studying chemistry at different levels of academic achievement did not have a significant difference in the organisations of concepts in the semantic network. The organisation of concepts combined by reaction time helps the chemistry education researchers to understand the form of the concept organisation in the long-term memory in-depth and to reflect the inadequacies of teaching practice.

Based on the overall results of this research, three implications are listed below. The first implication as a targeted suggestion for teaching practice is to deepen students' understanding of the relations between the relevant concepts and the concept 'chemical equilibrium'. Chemistry teachers can give more detailed descriptions of the relevant concepts to students and explain the key information of the concepts more deeply. Chemistry teachers can also conduct the learning tasks in which students apply the relevant concepts to interpret the progress and

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feature of chemical equilibrium and summarize the relations between concepts. The learning tasks are beneficial for students to increase the frequencies of concept usage and to restructure the organisation of concepts.

Next, the second implication regarding the research approach is to use the reaction time technique to conduct research studies on the organisation of science concepts. As shown in this research, the reaction time technique can be considered as an effective approach to acquiring students' judgment information to reflect the distance information of the concepts in the semantic network. Science education researchers can utilize this technique to explore the organisation of other science concepts and expand the knowledge of concept organisation.

Finally, the third implication based on the limitation of this research is to involve other appropriate tasks and techniques to acquire diverse evidence. This research only explored the organisation of concepts for students but not identified the relationship between the organisation of concepts and problem-solving ability of chemical equilibrium. In the future, by combining different kinds of task design in reaction time research and the paper-pen tests, the reaction time technique can be utilized as a supportive approach to depict how the organisation of concepts affects the performance of problem-solving. The findings will be helpful for researchers to gain a better understanding of the situation and function of the organisation of concepts.

Declaration of Interest

Authors declare no competing interest.

References

Akkus, H., Kadayifci, H., & Atasoy, B. (2011). Development and application of a two-tier diagnostic test to assess secondary students' understanding of chemical equilibrium concepts. *Journal of Baltic Science Education*, *10*(3), 146-155. http://www.scientiasocialis.lt/jbse/?q=node/224

Babai, R., & Amsterdamer, A. (2008). The persistence of solid and liquid naive conceptions: A reaction time study. *Journal of Science Education and Technology*, *17*(6), 553-559. https://doi.org/10.1007/s10956-008-9122-6

Babai, R., Brecher, T., Stavy, R., & Tirosh, D. (2006). Intuitive interference in probabilistic reasoning. *International Journal of Science and Mathematics Education*, *4*(4), 627-639. https://doi.org/10.1007/s10763-006-9031-1

Babai, R., Eidelman, R., & Stavy, R. (2012). Preactivation of inhibitory control mechanisms hinders intuitive reasoning. *International Journal of Science and Mathematics Education*, *10*(4), 763-775. https://doi.org/10.1007/s10763-011-9287-y

Babai, R., Sekal, R., & Stavy, R. (2010). Persistence of the intuitive conception of living things in adolescence. *Journal of Science Education and Technology*, *19*(1), 20-26. https://doi.org/10.1007/s10956-009-9174-2

Bain, K., & Towns, M. H. (2016). A review of research on the teaching and learning of chemical kinetics. *Chemistry Education Research and Practice*, *17*(2), 246-262. https://doi.org/10.1039/C5RP00176E

Barke, H.-D., Hazari, A., & Yitbarek, S. (2009). *Misconceptions in chemistry: Addressing perceptions in chemical education*. Springer-Verlag.

Bergquist, W., & Heikkinen, H. (1990). Student ideas regarding chemical equilibrium: What written test answers do not reveal. *Journal of Chemical Education*, *67*(12), 1000-1003. https://doi.org/10.1021/ed067p1000

Chiu, M.-H., Chou, C.-C., & Liu, C.-J. (2002). Dynamic processes of conceptual change: Analysis of constructing mental models of chemical equilibrium. *Journal of Research in Science Teaching*, *39*(8), 688-712. https://doi.org/10.1002/tea.10041

Collins, A. M., & Loftus, E. F. (1975). A spreading activation theory of semantic processing. *Psychological Review*, *82*(6), 407-428. https://doi.org/10.1037/0033-295X.82.6.407

Collins, A. M., & Quillian, M. R. (1969). Retrieval time from semantic memory. *Journal of Verbal Learning and Verbal Behavior*, *8*(2), 240-247. https://doi.org/10.1016/S0022-5371(69)80069-1

Danguecan, A. N., & Buchanan, L. (2016). Semantic neighborhood effects for abstract versus concrete words. *Frontiers in Psychology*, *7*, 1034. https://doi.org/10.3389/fpsyg.2016.01034

Finley, F. N., Stewart, J., & Yarroch, W. L. (1982). Teachers' perceptions of important and difficult science content. *Science Education*, *66*(4), 531-538. https://doi.org/10.1002/sce.3730660404

Foster, J. K. (2009). *Memory: A Very Short Introduction*. Oxford University Press.

Geeslin, W. E., & Shavelson, R. J. (1975). Comparison of content structure and cognitive structure in high school students' learning of probability. *Journal for Research in Mathematics Education*, 6(2), 109-120. https://doi.org/10.2307/748612

Gussarsky, E., & Gorodetsky, M. (1988). On the chemical equilibrium concept: Constrained word associations and conception. *Journal of Research in Science Teaching*, *25*(5), 319-333. https://doi.org/10.1002/tea.3660250502

Gussarsky, E., & Gorodetsky, M. (1990). On the concept "chemical equilibrium": The associative framework. *Journal of Research in Science Teaching*, *27*(3), 197-204. https://doi.org/10.1002/tea.3660270303

Hackling, M. W., & Garnett, P. J. (1985). Misconceptions of chemical equilibrium. *International Journal of Science Education*, *7*(2), 205-214. https://doi.org/10.1080/0140528850070211

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Huang, Y.-D., Yan, C.-G., Gao, H., & Zhou, Q. (2018). Gaozhong huaxue jiaoshi de xueke zhuti PCK biaozheng tanjiu: Yi "huaxue pingheng" weili [Characterization of senior high school chemistry teachers' topic PCK: Example of chemical equilibrium]. *Huaxuejiaoyu (Zhongyingwen) / Chinese Journal of Chemical Education*, *39*(7), 39-45. https://doi.org/10.13884/j.1003-3807hxjy.2016090089

Huddle, P. A., & Pillay, A. E. (1996). An in-depth study of misconceptions in stoichiometry and chemical equilibrium at a South African university. *Journal of Research in Science Teaching*, *33*(1), 65-77. https://doi.org/10.1002/(SICI)1098-2736(199601)33:1<65::AID-TEA4>3.0.CO;2-N

Jiang, N. (2012). *Conducting reaction time research for second language studies*. Routledge.

Johnstone, A. H., MacDonald, J. J., & Webb, G. (1977). Chemical equilibrium and its conceptual difficulties. *Education in Chemistry*, *14*(6), 169-171.

Jonassen, D. H., Beissner, K., & Yacci, M. (1993). *Structural knowledge: Techniques for representing, conveying, and acquiring structural knowledge*. Lawrence Erlbaum Associates.

Kantowitz, B. H., Roedige, H. L., III, & Elmes, D. G. (2008). *Experimental Psychology* (9th ed). Wadsworth Publishing.

Kousathana, M., & Tsaparlis, G. (2002). Students' errors in solving numerical chemical-equilibrium problems. *Chemistry Education: Research and Practice in Europe*, *3*(1), 5-17. https://doi.org/10.1039/B0RP90030C

Li, L. (2020). *Gaozhong like xuesheng 'yuandianchi' gainian jiegou de yanjiu* [Study on the conceptual structures of galvanic cell in high school science students] [Unpublished Master's thesis]. South China Normal University.

Liu, K., Zhang, X.-J., & Wu, X.-J. (2017). Huaxue hexin suyang peiyang de ketang xiaodu pingxi: Yi "huaxue pingheng de yidong " weili [Evaluating classroom validity of cultivation of chemical key competencies: Example of 'chemical equilibrium shift']. *Huaxuejiaoyu (Zhongyingwen) / Chinese Journal of Chemical Education*, *38*(5), 19-22. https://doi.org/10.13884/j.1003-3807hxjy.2016090031

Mai, Y., Qian, Y., Li, L., & Lan, H. (2021). The conceptual structure of chemical equilibrium in upper-secondary school students: Evidence from factor analysis. *Journal of Baltic Science Education*, *20*(1), 80-92. https://doi.org/10.33225/jbse/21.20.80

MoE (Ministry of Education, PRC). (2003). *Putong gaozhong huaxue kecheng biaozhun (Shiyan)* [National standard of general upper-secondary school chemistry curriculum (Experimental version)]. People's Education Press.

MoE (Ministry of Education, PRC). (2018). *Putong gaozhong huaxue kecheng biaozhun (2017 Nianban)* [National standard of general upper-secondary school chemistry curriculum (the 2017 version)]. People's Education Press.

National Education Examinations Authority. (2018). *2019 Nian putong gaodeng xuexiao zhaosheng quanguo tongyi kaoshi dagang (Like)* [National unified examination outline (Science) of general college entrance examination in 2019]. Higher Education Press.

Norman, D. A., Gentner, D. R., & Stevens, A. L. (1976). Comments on learning schemata and memory representation. In D. Klahr (Ed.), *Cognition and instruction*. Lawrence Erlbaum Associates.

Ollino, M., Aldoney, J., Domínguez, A. M., & Merino, C. (2018). A New Multimedia Application for Teaching and Learning Chemical Equilibrium. *Chemistry Education Research and Practice*, *19*(1), 364-374. https://doi.org/10.1039/C7RP00113D

Özmen, H. (2008). Determination of students' alternative conceptions about chemical equilibrium: A review of research and the case of Turkey. *Chemistry Education Research and Practice*, *9*(3), 225-233. https://doi.org/10.1039/B812411F

Recchia, G., & Jones, M. N. (2012). The semantic richness of abstract concepts. *Frontiers in Human Neuroscience*, *6*, 315. https://doi.org/10.3389/fnhum.2012.00315

Potvin, P., Masson, S., Lafortune, S., & Cyr, G. (2015). Persistence of the intuitive conception that heavier objects sink more: A reaction time study with different levels of interference. *International Journal of Science and Mathematics Education*, *13*(1), 21-43. https://doi.org/10.1007/s10763-014-9520-6

Qian, Y. (2008). *Gaozhong shisheng huaxue xueke guanjianci gainian jiegou de yanjiu* [A study on high school teachers and students' concept structure of keywords in chemistry] [Unpublished doctoral dissertation]. South China Normal University.

Quillian, M. R. (1968). Semantic memory. In M. Minsky (Ed.), *Semantic information processing*. MIT Press.

Soika, K., & Reiska, P. (2014). Using concept mapping for assessment in science education. *Journal of Baltic Science Education*, *13*(5), 662-673.

Solso, R. L., MacLin, O. H., & MacLin, M. K. (2014). *Cognitive psychology: Pearson new international edition* (8th ed). Pearson Education Limited.

Song, X. Q. (Ed.) (2007a). *Huaxue 2* [Chemistry 2] (3rd ed). People's Education Press.

Song, X. Q. (Ed.) (2007b). *Huaxue fanying yuanli* [Principle of chemical reaction] (3rd ed). People's Education Press.

Song, Y., & Wang, L. (2016). Cujin xuesheng renshi fazhan de huaxue pingheng jiaoxue sheji yanjiu [Chemical equilibrium teaching designs for promoting students' cognitive development]. *Huaxuejiaoyu (Zhongyingwen) / Chinese Journal of Chemical Education*, *37*(15), 23-32. https://doi.org/10.13884/j.1003-3807hxjy.2016060023

Tang, W. (2019). *Gaozhong shisheng 'yanghua huanyuan fanying'gainian jiegou de yanjiu* [Study on the conceptual structure of redox reaction in high school teachers and students] [Unpublished Master's thesis]. South China Normal University.

Van Driel, J. H. (2002). Students' corpuscular conceptions in the context of chemical equilibrium and chemical kinetics. *Chemistry Education: Research and Practice in Europe*, *3*(2), 201-213. https://doi.org/10.1039/B2RP90016E

Wang, L. (Ed.) (2007). *Huaxue 2* [Chemistry 2] (3rd ed). Shandong Science and Technology Press.

Wang, L. (2018). *Gaozhong shisheng 'lizi fanying' gainian jiegou de yanjiu* [A study on high school teachers and students' conceptual structure of ionic reaction] [Unpublished doctoral dissertation]. South China Normal University.

Wang, M. Z., Gao, P. L., & Wang, L. (Eds.) (2007). *Huaxue fanying yuanli* [Principle of chemical reaction] (3rd ed). Shandong Science and Technology Press.

https://doi.org/10.33225/jbse/21.20.443

Wang, Z. H. (Ed.) (2014a). *Huaxue 2* [Chemistry 2] (5th ed). Jiangsu Education Publishing House.
Wang, Z. H. (Ed.) (2014b). *Huaxue fanying yuanli* [Principle of chemical reaction] (5th ed). Jiangsu Education Publishing House.
Wilson, J. (1996). Concept maps about chemical equilibrium and students' achievement scores. *Research in Science Education*, *26*(2), 169-185. https://doi.org/10.1007/BF02356430
Wilson, J. M. (1994). Network representations of knowledge about chemical equilibrium: Variations with achievement. *Journal of Research in Science Teaching*, *31*(10), 1133-1147. https://doi.org/10.1002/tea.3660311007
Zhu, Y., Zhang, L., Leng, Y., Pang, R., & Wang. X. (2019). Event-related potential evidence for persistence of an intuitive misconception about electricity. *Mind, Brain, and Education*, *13*(2), 80-91. https://doi.org/10.1111/mbe.12188

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EXPLORING IN-SERVICE SCIENCE TEACHERS' BELIEFS ABOUT GOALS OR PURPOSES OF SCIENCE TEACHING

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Abstract. *Research indicates that teachers' beliefs about goals or purposes of science teaching, as one dimension of science teaching orientations, influence what happens in the classroom. The purpose of this research was to explore the self-reported and enacted goals or purposes of science teaching of four in-service Malawian science teachers using the curriculum emphases concept as a theoretical lens. This research used qualitative case study research design. Semi-structured interviews and classroom observations were used to explore teachers' self-reported and enacted goals or purpose of science teaching, respectively. A deductive analysis approach was used to analyze interview and classroom observation transcripts, to understand the teacher's goals or purposes. Results reveal that while teachers have multiple self-reported goals or purpose of science teaching, most of these are not enacted during teaching in the classrooms. This suggests the topic-specific nature of the goals or purposes. Results also show that all the teachers were not aware of the self-as-explainer goal or purpose of science teaching both during interviews and instruction. These findings are discussed, and implications are proposed for science in-service teacher professional development and pre-service teachers' training programs.*

Keywords: *science teachers' beliefs, curriculum emphasis, goals or purposes, science teaching orientations, teacher professional knowledge*

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Introduction

The performance of Malawian secondary school learners is poor at national-level assessments. This is especially true for science-related subjects as the chief examiners' reports for science highlight. Even though there is an improvement in the overall pass rate for learners at this level over the years (from 48% in 2006 to 60% in 2016), the situation remains worrisome since learners' performance in science remains poor. The chief examiners' reports for science have advanced several reasons. In the reports, they highlight issues such as *students' failure to apply the concepts they learn in class, students' failure to appreciate what science is, how it is conducted, poor foundation in as far as the use of other scientific skills is concerned and poor scientific skills that are displayed by the learners* during assessment (Malawi National Examinations Board, 2013, 2014, 2015). This is rather a depressing issue as it is happening when one of the objectives of science teaching at this level is to inculcate various skills that are instrumental in the learning of science such as reasoning, problem-solving and instrument manipulation skills (Ministry of Education, Science and Technology, 2013). A closer look at these highlighted factors speaks directly to the curriculum emphasis categories, developed by Roberts (2015), which in this research have been called goals or purposes of science teaching. There have been efforts by both the ministry of education and non-governmental organization to curb the issue of poor performance by learners in science. For instance, the Malawi Ministry of Education Science and Technology (MoEST), in conjunction with the Japanese International Cooperation Agency (JICA), launched a Strengthening of Mathematics and Science in Secondary Education (SMASSE) project in 2004. This Professional Development (PD) program was aimed at equipping teachers with novel techniques of effective science teaching as well as enhancing the development of their beliefs and Pedagogical Content Knowledge (PCK) (World Bank, 2010). Despite these reform efforts, Nampota (2016) noted that teaching science remains poor and that student performance in science remains largely unimpressive. The chief examiners' still highlight the same factors that lead to poor student performance in sciences. It is for this reason that the research explores the goals or purposes that Malawian science teachers set out when they are teaching science to their learners. Teachers'"goals or purposes of science teaching" are beliefs that describe the teachers'"conceptions about the function of science education in general" (Friedrichsen et al., 2011, p. 371).

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Theoretical Framework

The curriculum emphasis concept guided this research as a theoretical framework. This was developed as a way for "understanding and distinguishing among broadly different educational objectives that have characterized school science programs in recent history" (Roberts, 2015, p. 264). The underlying assumption in this concept is that the teaching of science subjects at any school level has fundamental reasons as to why the subject is offered at that level. By examining science textbooks, "high-profile classroom materials" as well as "curriculum policy statements from North America and England" from the 1900s, Roberts identified that these documents contained groups of information that suggested the objectives why a topic is taught to the learners. He called these groups of information "curriculum emphases." For example, some curricular documents emphasize on students retaining manipulative skills. In his 1982 paper, the author defined the concept of curriculum emphasis as follows:

> "A curriculum emphasis in science education is a coherent set of messages to the student about science (rather than within science). Such messages constitute objectives which go beyond learning the facts, principles, laws, and theories of the subject matter itself- objectives which provide answers to the student question: "Why am I learning this?" The answer to that question differs significantly for the Burns text and the PSSC text just noted" (Roberts, 1982, p. 245)

From the author's perspective, the primary purpose of teaching science is not only limited to the teaching of science content that appears in various science textbooks but that there also exist several purposes for teaching science to students at a particular level. These reasons are either stated explicitly or implicitly by curriculum designers. According to Roberts (1982), the notion of curriculum emphasis is critical in both teaching and learning of science as well as the development of the curriculum. To the teaching and learning of science, it helps to respond to the frequently asked question by students; "why we are learning this subject?" On the other hand, to curriculum developers, it helps them to answer the question; "why offering this content to learners." From his analysis of the said documents, he identified seven curriculum emphases described in Table 1. As noted by Van Driel et al. (2008) the seven curriculum emphases characterize orientations to teaching. In this research, the notion of curriculum emphases was used to map the teachers' goals or purposes of science teaching.

Table 1
Curriculum Emphases Described by Roberts (1982)

No	Curriculum emphasis	Description
1.	Everyday Coping (Everyday Application)	Concerns the teaching of science so that students understand or appreciate the importance of science in everyday life.
2.	Structure of Science	This concerns the teaching of science to students in such a way that students understand and appreciate the basic nature of science e.g., what constitutes scientific knowledge, how scientific knowledge is generated etc.
3.	Science, Technology, and Decisions (STS; Science, Technology, and Society)	This concerns the teaching and learning of science to demonstrate how science relates to other fields such as technology as well as decision making.
4.	Scientific Skill Development	This concerns teaching science to students so that they develop sound scientific skills such as problem- solving or these skills are critical in scientific knowledge generation.
5.	Correct Explanation	This concerns the teaching of science so that students can explain phenomena in their environment.
6.	Solid Foundation	This concerns the teaching and learning of science as a preparatory tool for other related science courses at a higher level such as university hence teaching students science at this certain level prepares them to understand science at a higher level.
7.	Self as explainer	This concerns what the self-conveys in science learning that includes aspects such as cultural values when generating scientific knowledge

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According to Roberts, the emphases described in Table 1 are choices that are influenced by "societal forces and concerns at different times in history" (Roberts, 2015, p. 264). This strongly suggests that curriculum emphases might be different from one society to the other. Considering the dynamic nature of society, they might change from time to time. In his review, he reports that some emphases that used to be more pronounced in the 1980s no longer retain the same status in the present day. For instance, *Science, Technology, Decisions* emphasis, which initially used to be more dominant and had several instances from the curricular documents no longer retain the same status (Roberts, 2015). This also brings to light the idea which Roberts also highlighted in his original publication – that the seven proposed categories are not exhaustive of the curriculum emphases that do exist. Since these curriculum emphases are either explicit or implicit, it is up to the teacher to interpret the intentions of the curriculum framers and implement the same. These interpretations might be different from teacher to teacher.

Roberts (1982) argued that the curriculum emphasis concept should be taken as "an analytical framework for understanding what is involved for policymakers, and science teachers when they shape their answers to the question: 'What counts as science education?'" (Roberts, 1988, p. 27). Against this background, several projects were conceptualized around this analytical framework. For instance, van Driel et al. (2008) reported on the curriculum emphasis of chemistry teachers in the Netherlands. Demirdöğen (2016) used the curriculum emphasis concept to analyze the teachers' "goals or purposes of science teaching" when she examined the interaction between STOs and PCK components. Hansson et al. (2021) also used the curriculum emphasis framework to research secondary science teachers' views about physics teaching. It is for this reason that this research also adopted the curriculum emphasis concept as a theoretical setting and analytical tool to underpin it. However, instead of calling them curriculum emphases, the research preferred to call them "goals or purposes of science teaching" to align with the focus of this research.

Research Aim and Research Questions

This research aimed at exploring the specific goals or purposes the science teachers do manifest when they are talking about science or teaching science. The following research questions guided this research:

1. What beliefs about goals or purposes of science teaching (if any) do the science teachers have?
2. Which of the self-reported goals or purposes of science teaching are enacted during teaching by the science teachers?

Research Methodology

Research Design

Science teachers' beliefs and classroom practices have always been researched qualitatively. This research also utilized a qualitative research design stemming from the interpretivist paradigm (Creswell, 2012) and used a case study design (Hancock, 2006) to allow for exploration and analysis of science teachers' beliefs about goals or purposes of teaching science. Data collection ran for the whole of the third term of the 2019 academic year (from September 2019 to December 2019).

Participants

Four Physical Sciences teachers were purposively sampled to take part in this research. These teachers were sampled because they had been teaching Physical Sciences at least for the past 5 years hence they had considerable experience in teaching sciences at this level. The other reason for selecting the teachers was that they had physics or chemistry as one of their majors in their teaching qualification. The assumption was that this would resemble a good understanding of the teaching and learning process. Table 2 illustrates the profile of the teachers and their contexts.

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Table 2
Profile of the Participants

Participant	Code	Gender	Experience (years)	Grade (form)	Majors	Qualification	Subject
Teacher 1	T1	M	6	1	PHY/MAT	Diploma	PHY
Teacher 2	T2	M	12	2	CHE/BIO	Degree	CHE
Teacher 3	T3	M	6	4	PHY/CHE	Degree	PHY
Teacher 4	T4	M	10	3	PHY/MAT	Diploma	CHE

Key: PHY—Physics, CHE—Chemistry, BIO—Biology, MAT—Mathematics, Sch—school
As can be seen in Table 2, all teachers are trained to teach physics and/or chemistry.

These teachers were selected from three different secondary schools (see Table 3) within Zomba urban education district. Two of these schools were Conventional Secondary Schools (CSS), and one was a Community Day Secondary School (CDSS). The difference between CSS and CDSS schools in Malawi is that CSSs are better resourced than CDSSs in terms of teaching resources and infrastructure for learning, such as laboratories. For instance, the two CSSs had laboratories with running water and power sockets and well-stocked libraries as shown in Table 3.

Table 3
Description of the Schools from which the Teachers were Sampled

School	Secondary school type	Description	Duration of a single lesson
School 1	Conventional Secondary School (CSS)	• Has laboratories • Has boarding facilities	40 minutes
School 2	Community Day Secondary School (CDSS)	• No labs • No boarding facilities • Double shift school (schools that have a different set of pupils in the mornings and afternoons) • Students commute from home	30 minutes
School 3	Conventional Secondary School (CSS)	• Has laboratories • No boarding facilities • Double shift school • Students commute from home	30 minutes

Instruments

Interviews

Semi-structured interviews were used to gather data (Cohen et al, 2007). Using an interview schedule that was adapted from Demirdöğen (2016), interviews were conducted with each of the four teachers that took part in this research. The interview schedule was piloted with three science teachers who did not form part of the sample to test its reliability in this context. The piloting exercise allowed us to rephrase some of the unclear phrases. At first, questions were asked as presented in the adopted interview schedule. However, it was realized that it was imperative to provide more information about the questions to the teachers so that they understand the questions. This led to the production of a valid instrument for use in the research (Cohen et al., 2007). The interview schedule had seven questions that interrogate the teachers' beliefs about their goals or purposes while they teach science to

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their learners. These interviews were conducted individually at the teachers' appropriate time and place and they all lasted between 60 minutes to 80 minutes. Teachers were asked to articulate issues such as their purposes when they teach science, the things that their students should know when they learn science, the kind of knowledge and capabilities students should learn when they learn science etc.

Classroom observations

To examine evidence of the goals or purposes of science teaching during the actual teaching, classroom observations were conducted. The four teachers were asked to be observed on a topic of their choice during the data collection phase. Each teacher was observed two times to get an overview of which of their beliefs (as self-reported) about the "goals or purposes of science teaching" are displayed in their classrooms during teaching. Table 4 below shows the observed lessons per teacher.

Table 4
Summary of Lessons Observed for all the Teachers

Teacher and school	Lesson topic and duration
Teacher 1 (School 1)	1. Energy (40 minutes) 2. Electric current (80 minutes)
Teacher 2 (School 3)	1. Specific heat capacity (30 minutes) 2. Machines (60 minutes)
Teacher 3 (School 3)	1. Magnetism (60 minutes) 2. Electricity, magnetism and electric induction (60 Minutes
Teacher 4 (School 2)	1. Electricity—electrical energy and power (30 minutes) 2. Electricity—electromagnetic induction (60 minutes)

As can be seen in Table 4, the four teachers were teaching different topics during the observation period. The duration of each observed lesson depended on the school's timetable structure (see Table 3). To capture the teachers' voices and actions for analysis of the episodes that demonstrate teachers' goals or purpose of science teaching during instruction, the lesson observations were video-recorded.

Data Analysis

Audio-recorded interviews, as well as classroom observations, were transcribed verbatim for analysis. Using deductive data analysis approach (Patton, 2002), the two authors first discussed the analytical framework (*components of curriculum emphasis*) to have a common understanding. They then coded the first interview transcript separately using the pre-determined themes developed by Roberts (1982, 1988, 2015) then came together to discuss the assigned codes in transcripts. There were some differences which they had to discuss and iron out. Thereafter, they coded the second transcript from classroom observations to familiarize and acquaint with the coding process discussed and agreed upon and compared the coding again and there was a 90% agreement. In the observation transcript, the interest was on the evidence from teachers' talk or episodes during teaching that aligns with the descriptions of curriculum emphases by Roberts (1982). After the coding of the second transcript, the first author then coded the rest of the transcripts (both from the interviews and the observations). Each transcript was assessed for evidence for any of the seven curriculum emphases—referred to as "goals or purposes of science teaching" in this research. Responses were given a number from 1-7 representing the seven goals or purposes of science teaching. The number of instances where each teacher showed evidence of each of the seven categories of goals or purposes in both the interview and observation transcripts were counted.

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Research Results

The results for each teacher in terms of the goals or purposes of science teaching they self-reported and displayed during teaching are presented below.

Teacher 1

Table 5 below illustrates the number of instances Teacher 1 referred to each of the seven categories of goals or purposes of science teaching during the interviews (self-reported) and how frequent the self-reported goals or purposes of science teaching manifested during teaching.

Table 5
Summary of Teacher 1's Self-reported and "enacted" Goals or Purposes about Science Teaching

No.	Category of goals or purposes to science teaching	Frequency as self-reported	Frequency of "episodes" during teaching
1.	Everyday coping	2	2
2.	Structure of Science	1	1
3.	Science, Technology, and Decisions (STS; Science, Technology, and Society)	1	0
4.	Scientific skill development	1	0
5.	Correct explanation	1	0
6.	Solid foundation	1	3
7.	Self as explainer	0	0

As can be seen in Table 5, Teacher 1 revealed awareness of almost all the categories of the goals or purposes to science during interviews except for self as explainer. For instance, in terms of everyday coping, the teacher held a view that the purpose of science teaching was to help students get familiar with everyday occurrences by stating "*you want to instil skills to the students so that these students when they acquire these skills, knowledge, they utilize it in their everyday life*." He believed that once students learn and master the various skills in science, they will be able to live and cope with what the environment demands of them. Furthermore, concerning solid foundation goal, the teacher also held the view that science teaching should prepare students for science courses that they are going to do at a later stage as he states:

> We talk about different courses in colleges, whereby these courses also require the Physics/Chemistry which we are talking about. It's like we are teaching science so that we prepare these students so that they achieve their goals, they achieve their dreams and also instilling the pre-requisite knowledge there which is going to be used at a later stage after they finish secondary school.

In contrast, most of Teacher 1's self-reported goals or purposes did not manifest during his teaching. As seen in Table 5, only three of the categories (i.e., *everyday coping, structure of science, and solid foundation* goals or purposes manifested at least once). The manifestation of everyday coping was in such a way that the teacher tended to ask questions that required the students to link what they have learnt to everyday life. For instance, when he was teaching about electric current, towards the end of the lesson, he asked the students to explain how electric current relates to their everyday life. *Additionally*, when he was teaching about energy—specifically renewable sources of energy, he tended to ask students to relate each source of energy to everyday life. Concerning solid foundation, the teacher used a variety of techniques to ensure that students understand the concepts. For instance, he varied the pace of his lessons—to cater for slow learners and repeat what he had just said or use sometimes vernacular language—to cater for students who had language deficiencies. He claimed that the use of these techniques helped to take into consideration the weaknesses of a particular technique hence ensure that every student understands what he was saying.

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Teacher 2

Table 6 summarises the frequency where goals or purposes of science teaching for both reported and enacted were coded for Teacher 2.

Table 6
Summary of Teacher 2 Self-reported and "enacted" Goals or Purposes about Science Teaching

No.	Category of goals or purposes to science teaching	Frequency as self-reported	Frequency of "episodes" during teaching
1.	Everyday coping	1	5
2.	Structure of Science	0	0
3.	Science, Technology, and Decisions (STS; Science, Technology, and Society)	1	0
4.	Scientific skill development	1	1
5.	Correct explanation	1	2
6.	Solid foundation	0	3
7.	Self as explainer	0	0

Except for self as explainer, the teacher seemed to be aware of almost all the goals or purposes of science teaching as shown in Table 6. The teacher claimed that the teaching of science should be conducted in such a way that *"…students master the basic concepts in science, such as theories, laws, etc."*. What is coming out from this utterance is that by learning about the various theories, laws, facts and principles, students will understand how things work and be able to explain phenomena. As a result, students will achieve the correct explanation goal of science teaching. To ensure that students achieve both correct explanation and solid foundation, the teacher said that there is a "*need to vary instruction process so to ensure that they cater for the deficiencies of a particular strategy*."

During teaching, some of the goals manifested themselves more than they were said in the interviews as shown in summarising the frequency where goals or purposes of science teaching for both reported and enacted were coded for Teacher 2. For this teacher, the entire teaching process appeared to be driven by *everyday coping* goal or purposes of science teaching as several episodes were illuminating this belief. For instance, to achieve this everyday coping goal or purposes, the teacher tended to pull examples that students were familiar with as shown in the extract below:

1	-	Teacher	:	So, let's look at the types of simple machines. So, the first category is force multipliers […] This machine has the duty of multiplying this small load to become a significant force […] lift this massive load. For example, a **car jack** […]
2	-	Teacher	:	Can somebody try to describe how a car jack works?
3	-	Student	:	A car jack works by winding [*he demonstrates what he means by winding*] – so there it multiplies the force.
4	-	Teacher	:	Now you will see that you will use only one hand – just only one hand whether he is winding or trying to put it up or down. But what comes out of this using just one hand, you will see a car being lifted. So, you see that is why we say this car jack is multiplying the force that you are applying.
5	-	Student	:	Listen
6	-	Teacher	:	[*having discussed the previous examples at length, the teacher moved to a second example*] … Let's go to the second category – distance multipliers. As the name suggests, there is a movement or some kind of movement … for a movement within a small distance moves through a large distance. Do you understand why it is called a distance multiplier?

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7	-	Students	:	Yes
8	-	Teacher	:	What do you think can be a good example of a distance multiplier?
9	-	Student	:	Oxcart
10	-	Teacher	:	Not really. But a good example is the bicycle axle.

In turn 1, the teacher is illustrating that a car jack is a good example of simple machines that belong to the category of simple machines. He used examples of bicycles just outside the classroom. Since this was CDSS (see Table 3), most learners commute from their homes to school using bicycles which may have prompted the teacher to mention this example. This signifies the critical role of context in the teaching and learning of science.

Teacher 3

Table 7 summarises the frequency where goals or purposes of science teaching for both reported and enacted were coded for Teacher 3.

Table 7
Summary of Teacher 3 Self-reported and "enacted" Goals or Purposes about Science Teaching

No.	Category of goals or purposes to science teaching	Frequency as self-reported	Frequency of "episodes" during teaching
1.	Everyday coping	3	0
2.	Structure of Science	1	0
3.	Science, Technology, and Decisions (STS; Science, Technology, and Society)	4	0
4.	Scientific skill development	1	3
5.	Correct explanation	1	2
6.	Solid foundation	0	2
7.	Self as explainer	0	0

Just like the two other teachers reported above, Teacher 3 also demonstrated to have multiple goal or purposes of science teaching during interviews of which some were manifested during teaching. Concerning science, technology, decisions, goal or purposes of science teaching, his narration suggested that he teaches science so that students utilize the science knowledge to solve various problems affecting their lives. He expressed how satisfied he becomes whenever students utilize scientific knowledge to develop products that could be used to solve various problems as shown below:

> I become thrilled when learners come back, 'sir, you taught us this, now we have used this idea to produce this item'. I become pleased, and I follow those, those productions from the learners … they have done some materials which are in the lab, the materials [things] which I could not think that they can produce, but they produce the materials just because, to me, it was like feedback, to say 'ok you taught us this now we have produced this. So, to me, that's ok and for a learner to say 'ok I have produced this thing from the knowledge I had, to me, what it applies is that, ok, it means this learner understood what I taught yea and then can apply because to reach an application-level, it means that you have theoretically understood the concept

Furthermore, the teacher's sentiments suggested that he teaches science to the students to enhance their understanding of the nature of science or structure of science in the process:

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> …the other thing is that, aaa the little part I can assist the learners to learn the discipline of science, they may help them to live or to sustain, they may help to themselves to sustain in the communities.

While the teacher talked more concerning *science, technology, decisions,* goal or purposes of science teaching (see Table 7), he did not show any evidence of this goal or purposes during teaching. On the contrary, the teacher focused on achieving goals such as scientific skills development and solid foundation goal or purposes. For instance, to ensure that students develop scientific skills (*measurement, observation recording and calculations*), the teacher planned to use practical work where students would determine the behaviour of resistance in both series and parallel circuits as shown in the extract below:

1	-	Teacher	:	Now I want you to divide yourselves into two groups. I want you to have the two kinds of circuits…series and parallel as shown on the board
2	-	Student	:	Students listen to the instructions of the teacher
3	-	Teacher	:	So, in series circuit what you are going to have is the cells arranged like this [*he points to the board*], You can use maybe two cells and then from the two cells you will have two resistors—two resistors like this [*he points to the board again*] and then you will also have an ammeter here and then a voltmeter here. So, this one is voltmeter 1 on resistor 1 and then on resistor 2, you will have voltmeter 2.
4	-	Student	:	Students listen to the instructions of the teacher
5	-	Teacher	:	What is the behaviour of current in a series circuit? [*teacher asks a question for the students to recall the previous knowledge*]
6	-	Students	:	Current is the same at any point in the series circuit.
7	-	Teacher	:	Therefore, construct a circuit as shown on the board [he points at a circuit on the board] take the necessary measurements and record the findings
8	-	Student	:	In their groups, students construct the circuits, take measurements of current and then record their findings
9	-	Teacher	:	Once you have recorded your findings, determine V1 and V2 [he explain this as he points at a circuit diagram on the board]
10	-	Student	:	Students determine the values of both V1 and V2 from their recordings
11	-	Teacher	:	…so, for part two instead of having these voltmeters, you are going to have one voltmeter across all the two resistors.
12	-	Student	:	Students listen to further instructions from the teacher
13	-	Teacher	:	Now let's have representatives from each group—from group 1 and group 2 give us the values; can I have the values for the first part in the series circuit what do we have. You can come here and write.
14	-	Student	:	Representatives from each group present their findings
15	-	Teacher		Now, what about resistance—resistance for R1 and resistance for R2? And what can you about the behaviour of resistance in both types of circuits? [*Teacher further asks probing questions for students to interrogate their results*]
16	-	Student	:	Students present the **calculated** values of R1 and R2

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In the above extract, we see how the teacher strived to achieve critical scientific skills. In turns 1 and 3, the teacher told the learners the aim of the lesson which was about the behaviour of resistance in both types of circuit. Specifically, the teacher wanted the students to learn about total resistance for both series and parallel. Such kind activities, the teacher believes, enhanced students' development of scientific skills such as interaction with the materials, recording as well as measurements (turn 8) and calculation (turn 16). Similarly, towards the end, students were asked to present their findings. It is believed that this gave the students a chance to hone their presentation skills. All these are scientific skills that students need to learn as they learn science.

Teacher 4

Table 8 summarises the frequency where goal or purposes of science teaching for both reported and enacted were coded for Teacher 4.

Table 8
Summary of Teacher 4 Self-reported and "enacted" Goals or Purposes about Science Teaching

No	Category of goals or purposes to science teaching	Frequency as self-reported	Frequency of "episodes" during teaching
1.	Everyday coping	3	0
2.	Structure of Science	0	0
3.	Science, Technology, and Decisions (STS; Science, Technology, and Society)	2	0
4.	Scientific skill development	3	0
5.	Correct explanation	0	3
6.	Solid foundation	2	4
7.	Self as explainer	0	0

Just like the other three teachers, Teacher 4 was aware of almost all the goals or purposes of science teaching except for self as explainer goal. For instance, during interviews, he narrated that teaching and learning science helps learners to understand their surroundings. He explained the applicability of scientific knowledge to everyday life by citing simple everyday life phenomena that can be explained using scientific knowledge, as shown in the quote below:

> … For example, at home, there is the application of science, it's when they are cooking, there is a lot of science there. Yeah so, even as an individual, walking you know from one place to the other, there is a lot of application of science. And the commodities that being produced nowadays, there is a lot of science in there. Yeah, so we cannot run away from that. Yeah, those are just a few examples

This extract provides evidence of the teachers' orientations regarding *everyday coping* goal or purpose of science teaching. The teacher's comment suggests that science teaching is connected to our everyday lives, hence the teacher considers that science teaching is not an isolated aspect divorced from everyday life, but something that directly relates to and is applicable in explaining aspects about people's surroundings. He also went further to explain that the teaching and learning of science help "*our students to grow in science because wherever they go, they will apply that science…*". This suggests a solid foundation goal of science. Once students have a solid foundation, they will be able to use that knowledge when learning science courses in higher education.

Some of the goals of science the teacher elucidated during interviews manifested in the classroom during teaching. For instance, while teaching about chemical reactions, and despite being the least talked about the goal or purposes of science teaching, solid foundation goal manifested itself. The teacher used POE teaching strategy to ensure that students understand the concepts he was teaching. Predict Observe Explain (POE) is an active teaching strategy that was developed by Gunstone and White (1992). This strategy accords students a chance to observe and

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then explain what they are observing or make a prediction and then explain their reasoning. Using this strategy, the teacher asked the students to predict what would happen to the mass (of both reactants and products) during a chemical reaction and to further support their guess with a scientific explanation as shown below:

1	-	Teacher	:	If the reactants form a new product like this one [*points at a chemical equation on the board*] … do we expect the mass of the reactants to be different from those of the products?
2	-	Students	:	Yes [*Students responded*]
3	-	Teacher	:	A chemical reaction is the rearrangement of atoms to form a new substance. Here we have reactants and, of course, products. Now, if a new substance is formed, is the mass of reactants different from the mass of products? [*teacher tries to rephrase the question so that students understand it*]
4	-	Student	:	Yes, it is different? [*one student responds*]
5	-	Teacher	:	Who else? Are they different? Why do you think the mass of reactants will be different from the mass of the products?
6	-	Student	:	Yes. Because they have rearranged themselves to form a new substance
7	-	Teacher	:	In fact, during a chemical reaction, no atoms are formed, and also no single atom is destroyed

In the course of achieving a solid foundation goal of science teaching, the teacher aims to ensure that students have a good understanding of the concepts in science. One way of achieving this is through the use of active teaching strategies where learners are engaged in the thinking process. By using the POE strategy above, the teacher engaged the student's minds-on. This is in the sense that students were encouraged, through questioning, to reason through their ideas which they have presented to the class as shown in turn 5.

Table 9 illustrates an overview of the prevalence of the self-reported and enacted goals or purposes of science teaching" for each teacher. The table below is used to discuss the findings below.

Table 9
Summary of Teachers' Self-reported or Enacted Categories of Goals or Purposes of Science Teaching

Category of goals or purposes of science teaching	Number of instances for each teacher as self-reported and enacted							
	Teacher 1		Teacher 2		Teacher 3		Teacher 4	
	R	E	R	E	R	E	R	E
Everyday coping	2	2	1	5	3	0	3	0
Structure of Science	1	1	0	0	1	0	0	0
Science, Technology, and Decisions	1	0	1	0	4	0	2	0
Scientific skill development	1	0	1	0	1	3	3	0
Correct explanation	1	0	1	2	1	2	0	3
Solid foundation	1	3	0	3	0	2	2	4
Self as explainer	0	0	0	0	0	0	0	0

Key: R – Self-reported; E – Enacted during teaching

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Discussion

In the previous section, the findings for individual teachers in terms of the categories of goals or purposes of science teaching as self-reported and seen during teaching were presented. For discussion purposes, the findings are summarised in Table 9 above.

The research showed that all four teachers had multiple self-reported goals or purposes of science teaching. This is consistent with previous studies. For example, Friedrichsen and Dana (2005) found that teachers held multiple goals or purposes of science teaching. The most self-reported goal of science teaching is everyday coping. Although some teachers reported on the correct explanation goal, Teacher 4 did not report on any. Likewise, Teachers 2 and 3 did not report on solid foundation goal or purpose although it manifested in the classroom portraying the teachers as those that aim to prepare their students for the next levels in terms of content knowledge. The prevalence of everyday coping could mean that their purposes of teaching science are mostly about teaching the content knowledge as prescribed by the instructional materials like textbooks. The findings suggest that the teachers believed that using everyday examples could equip students with the necessary scientifically correct knowledge to use outside the classroom. Ekiz-Kiran and Boz (2020) also found the same pattern with chemistry teachers – teachers reporting mostly on everyday coping as their goals of teaching science. The dominance of everyday coping and solid foundation purposes as shown in this research may be due to the overemphasis of this goal of science teaching in both curricular, other government official documents and the media could explain this observation. For instance, in documents such as the Malawi Growth and Development Strategy (MGDS 1, 2, 3), Millennium Development Goals (MDG), National Science and Technology Policy (NSTP), they treat science as that subject that prepares students' survival in the society. This is because they acquire various critical skills that enable them to 'identify and solve current as well as emergent problems' (Ministry of Education, Science and Technology [MoEST], 2013). Such presentation of science in critical documents, it is believed, creates an impression amongst science teachers to the extent that other equally important aspects about the goals and purpose of science teaching seem subsumed into this. As argued by Azam (2020) and Friedrichsen and Dana (2005), contexts such as curriculum materials, school ethos, etc., play a significant role in shaping the beliefs of the teachers which they articulate or manifest during teaching. Similarly, Suh and Park (2017) indicate that the policies and socio-political priorities that teachers are exposed to tend to influence what teachers conform to in terms of beliefs.

The fact that other goals like structure of science and scientific skills development purposes as proposed by Roberts (1988) are less reported on, raises concerns about the teaching and learning of science. The teachers showed less awareness of *structure of science* as the goal of teaching science. The structure of science is complex emphasis where teachers who possess such goals would move from just focusing on providing correct content to conceptualizing and analyzing the content as a conceptual system (Roberts, 1988). Since research indicates that beliefs about science teaching are influenced by the school contexts in which teachers teach in (e.g., Mavuru & Ramnarian, 2018), the expectation was that Teachers 2 and 3 should have scientific skills development because they are teaching in a well-resourced school (availability of well-resourced laboratories – see Table 3 for the school context) and Teacher 1 to seldom report on this goal. Furthermore, this goal seldom manifested during their teaching excerpt for Teacher 3. The research showed the opposite – that the context in which one is teaching may not necessarily influence the orientations that teachers have. However, Teacher 4, who is also teaching at a school with laboratories illustrated having this goal, but this did not manifest at all during his teaching. As argued by Ekiz-Kiran and Boz (2020) and van Driel et al. (2008), science teachers should show evidence of having more goals of teaching science that resemble emphasis on scientific inquiry and process skills.

An interesting finding to observe in this research is that while all the teachers had multiple self-reported and enacted goals of science teaching, *self as an explainer* was neither self-reported nor manifested during teaching. This was a quite surprising finding since all the teachers did not talk about it nor manifest it during instruction despite being in the teaching service for more than 7 years on average. Ekiz-Kiran and Boz (2020) also indicated that self as explainer was not observed with the in-service chemistry teachers. One reason that potentially explains this observation is the structure of the science curriculum in Malawi. Again, a close examination of the documents revealed that neither the role of students' cultural background nor the history of science is explicitly discussed in the curriculum (see MoEST, 2013). While the curriculum is

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explicit about other goals such as structure of science, everyday coping, scientific skills development solid foundation, on the contrary, it is mute about the role of the learners, the role of the cultural background of the learners and the history of science in the learning process.

While teachers had multiple self-reported goals or purposes of science teaching, most of these goals did not manifest themselves during instruction (e.g., STS goal). While this might be taken as a misalignment of goals of science, the general view is that this observation suggests that goals of science are topic-specific. Azam (2020) noted that teachers' approach to teaching science must necessarily be different due to the demands of the nature of the concepts inherent in each topic as shaped by the curriculum and context. What this means is that for specific topics, a researcher would be able to observe specific goals being manifested during teaching. For instance, some topics are traditionally inclined to everyday coping purpose of science teaching than others. Topics such as electricity or power and machines offer more chances to link the concepts to everyday life than would be the case with other topics (see Kapucu, 2016). On the other hand, teachers did not report some goals or purposes of science teaching but were seen manifesting in their classrooms. The lack of proper language by the teachers to express themselves offers some insights in this regard. Baxter and Lederman (1999) argued that sometimes teachers do not know how to articulate the things that they do and why they take certain decisions when teaching science. This is because they simply do not have a proper language that they can use to express themselves. This could explain the observation. Furthermore, this is substantiated by the fact that although some teachers did not infer anything about solid foundation or correct explanation, the two categories of goals or purposes to science teaching frequently manifested in their classrooms. This does not demonstrate that teachers did not have these goals at the back of their minds, rather it signifies a lack of proper language to express themselves that they hold those beliefs.

Conclusions and Implications

This research was about exploring the in-service science teachers' self-reported and enacted goals or purposes of science teaching as one dimension of the STOs. Although the focus of the research was not on the alignment of goals when self-reported and seen during teachers' practice, the findings reveal some insights about what is claimed by the teacher and their practices in the classrooms. This insight is that teachers may voice out certain goal not to show that during teaching. Similarly, they may not self-report on certain goals of science teaching but still, show evidence of those in their classrooms during teaching. This demonstrates the fact that sometimes what teachers lack is the language to articulate their beliefs, adding to the complex nature of beliefs. An interesting finding in this research is the fact that all the teachers did not talk about self as explainer purpose that scientific skills development and STS did not manifest in most of the classrooms. This finding is concerning in terms of the quality of science teaching in the context of Malawi as it reveals a gap in the teachers' knowledge of the teaching orientations.

The findings have implications for the professional development of both in-service and pre-service teachers. In-service teachers should be professionally developed to enhance their knowledge about goals or purposes of science teaching. Instead of the widely known and held professional developments where an academic would 'lecture' science teachers on how to display the goals or purposes of science teaching in the classrooms, the suggestion in this research is that the professional developments should be characterized by teachers collaborating and reflecting on their planning of lessons and teaching such that this reveals their beliefs. The revelation of their beliefs may lead to how they can be challenged to have quality teaching and learning of science. For pre-service teachers, teacher training institutions could embed and discuss some of these issues with the teachers on the importance of making goals or purposes of science teaching explicitly. Spending considerable time discussing these issues with pre-service teachers during training would develop their belief systems.

Limitations and Future Studies

This research was conducted in the Malawian context with only four teachers. This is a small sample to conclude about the nature of science teaching and learning in Malawi but provides considerable insights

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for future studies. The main limitation of this research points to the data collection methods used. Since there was no post-observation interview with the teachers, the four teachers' classroom actions may not necessarily be directly related to specific goals or purposes of science teaching. It is for this reason that the research suggests more similar research and incorporate post-observation interviews to get teachers' reasoning behind their actions. In this research, the teachers were observed teaching different topics. Drawing from how teacher thinking and beliefs can vary across topics, the research suggests that more research needs to look at teachers' goals or purposes to science teaching across a particular topic.

Declaration of Interest

Authors declare no competing interest.

References

Azam, S. (2020). Locating personal Pedagogical Content Knowledge of science teachers within stories of teaching force and motion. *Eurasia Journal of Mathematics, Science and Technology Education*, *16*(12), ARTICLE em1907. https://doi.org/10.29333/ejmste/8941

Baxter, J. A., & Lederman, N. G. (1999). Assessment and measurement of Pedagogical Content Knowledge. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining Pedagogical Content Knowledge* (pp. 147–161). Springer Netherlands. https://doi.org/10.1007/0-306-47217-1_6

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed). Routledge.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed). Pearson.

Demirdöğen, B. (2016). Interaction between science teaching orientation and Pedagogical Content Knowledge Components. *Journal of Science Teacher Education*, *27*(5), 495–532. https://doi.org/10.1007/s10972-016-9472-5

Ekiz-Kiran, B., & Boz, Y. (2020). Interactions between the science teaching orientations and components of pedagogical content knowledge of in-service chemistry teachers. *Chemistry Education Research and Practice*, *21*(1), 95–112. https://doi.org/10.1039/C9RP00092E

Friedrichsen, P. M., & Dana, T. M. (2005). Substantive-level theory of highly regarded secondary biology teachers' science teaching orientations. *Journal of Research in Science Teaching*, *42*(2), 218–244. https://doi.org/10.1002/tea.20046

Friedrichsen, P., Van Driel, J. H., & Abell, S. K. (2011). Taking a closer look at science teaching orientations. *Science Education*, *95*(2), 358–376. https://doi.org/10.1002/sce.20428

Gunstone, R., & White, R. T. (1992). *Probing understanding* (1st ed.). Falmer Press.

Hancock, D. R. (2006). *Doing case study research: A practical guide for beginning researchers*. 122.

Hansson, L., Hansson, Ö., Juter, K., & Redfors, A. (2021). Curriculum emphases, mathematics and teaching practices: Swedish upper-secondary physics teachers' views. *International Journal of Science and Mathematics Education*, *19*(3), 499–515. https://doi.org/10.1007/s10763-020-10078-6

Kapucu, S. (2016). Identification of the physics subjects that are liked/disliked and why these subjects are liked/disliked by student teachers. *Journal of Theory and Practice in Education, 12*(4), 827–843.

Malawi National Examinations Board. (2013). *Chief examiners' reports for junior certificate examinations and Malawi senior certificate physics examinations.* Unpublished annual report.

Malawi National Examinations Board. (2014). *Chief examiners' reports for junior certificate examinations and Malawi senior certificate physics examinations*. Unpublished annual report.

Malawi National Examinations Board. (2015). *Chief examiners' reports for junior certificate examinations and Malawi senior certificate physics examinations*. Unpublished annual report.

Ministry of Education, Science and Technology. (2013). *Republic of Malawi syllabus for Physics forms 3 and 4.* Zomba: Malawi Institute of Education.

Nampota, D. C. (2016). Students' perspectives on teacher practices in Physical Science and their implications on inquiry-based instruction. In W. Mwakapenda, T. Sedumedi, & M. Makgato (Eds.), *Researching a sustainable environment and sustaining research in Mathematics, Science and Technology Education* (pp. 405–416). Routledge, Taylor & Francis Group.

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Sage Publications.

Roberts, D. (2015). Curriculum emphasis. In R. F. Gunstone (Ed.), *Encyclopedia of science education* (pp. 264–279). Springer Reference.

Roberts, D. A. (1982). Developing the concept of "curriculum emphases" in science education. *Science Education*, *66*(2), 243–260. http://onlinelibrary.wiley.com/doi/10.1002/sce.3730660209/full

Roberts, D. A. (1988). What counts as science education? In P. J. Fensham (Ed.), *Development and dilemmas in science education* (pp. 27–54). Falmer Press.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Roberts, D. A. (1995). Junior high school science transformed: Analyzing a science curriculum policy change. *International Journal of Science Education*, *17*(4), 493–504. https://doi.org/10.1080/0950069950170408

van Driel, J. H., Bulte, A. M. W., & Verloop, N. (2008). Using the curriculum emphasis concept to investigate teachers' curricular beliefs in the context of educational reform. *Journal of Curriculum Studies*, *40*(1), 107–122. https://doi.org/10.1080/00220270601078259

World Bank (Ed.). (2010). *The education system in Malawi*. World Bank.

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THE COMMON METAPHORICAL PERCEPTIONS OF PROSPECTIVE TEACHERS AS TO DNA-GENE-CHROMOSOME CONCEPTS

Banuçiçek Özdemir

Abstract. *This research was performed to determine the Common Metaphorical Perceptions of Prospective Teachers on DNA-Gene-Chromosome Concepts, despite classroom levels and university differences. For the baseline group studies, two State Universities, one from the east and the other from the north of Turkey, were selected to be studied in the Fall Semester of 2017-2018. They were respectively called University A" and "B". The population sample contained a total of 326 students from 1st, 2nd, 3rd, and 4th- classroom level of the "Science Education Department" of "Education Faculties." The phenomenology design which is one of the qualitative research methods was applied. Answers to questions regarding "the metaphors of DNA-Gene-Chromosome concepts" and "under what theoretical categories the common features and metaphors were investigated" to be in line with the university differences. The research data were obtained by 'metaphor identification' for respective concepts and content examination studies in the framework of "Qualitative Analysis Methods." Correspondingly, it has been determined that Prospective Teachers have common metaphors concerning DNA-Gene-Chromosome concepts, regardless of their class or university differences.*

Keywords: *prospective teachers, metaphorical image for DNA-gene-chromosome, phenomenological research, content analysis*

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Introduction

The Biology Training Program, designed in education, is based on the constructivist approach. This approach is the process of facts that individuals observe and make sense of, in their surroundings. They construct knowledge by serving to be interpreted individually, according to their experience (Driver & Bell, 1986). This process focuses on how to teach individuals or teachers to plan learning, rather than, accepting what is taught. Also, this is important for the functionality of information in place of content. Metaphors are one of the teaching strategies that aids to determine the state of known knowledge in teaching and how to teach it in future education. Therefore, metaphors are the most preferred teaching resources in science coaching (Harrison & Treagust, 2006; Jeppsson et al., 2013). One challenge in bringing science literacy to a certain level is the individuals that have a low chance of being correctly observed, in making sense of biological concepts. The interest in learning biology reduces due to the intense course content of the biology curriculum, not using the majority of information in daily life, consisting in more than one abstract concept, and having difficulties reflecting knowledge of learners (Banet & Ayuso, 1999; Gilbet, 2006;). Although this problem may appear in different disciplines, particularly, in the fields of physics, chemistry, and biology, the most focus is on the concepts of biology courses (Ekici, 2016). And that is why scholars have difficulty expressing, "what was learned and how to practice" in their lives (Banet & Ayuso, 1999; Chuang & Cheng, 2003; Pelaez et al., 2005). Also, having intensity concepts makes it difficult to understand, relationships between perceptions depend on biology information that has abstract exterior terminology. It is expected that micro concepts can be observed with a microscope. In addition, it is expected, the concepts that are theoretically close create confusion. In biology, it is hardly possible for each of the terminological terms to be observed. The information is limited in representative phenomena that individuals create in their minds. Through these phenomena, information is made meaningful and expressed according to meaning reflection. Besides, it is observed that excessive ter-

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minological terms in biology science create different metaphorical perceptions in mind that diverts them from meanings. In addition to the conceptual difference, the common metaphorical perceptions, which are issued to different variables, attract attention.

According to the study of Mahaffy (2006), it has been determined that students preferred to explain the concepts that have had difficulty in comprehending, with metaphors. Also, it was stated that interest levels of students decreased due to huge abstract concepts, especially, in science lessons (Gilbert, 2006). The metaphors that are used in education have a particularly important place in explaining mixed phenomena and concepts (Eaglestone, 2009; Semerci, 2007). In order to describe any phenomenon as a metaphor, three questions need to be answered.

1. What is the subject of metaphor?
2. What is the source of metaphor?
3. What are the characteristics simulated to the subject from its source of metaphor (Forceville, 2002)?

A metaphor is an explanation of a determined phenomenon-case or idea with another case-phenomenon or concept (Kövecses, 2002; Oxford et al., 1998). The word Metaphor derived from "Metapherein", as well as, originated from the combination of two Greek words, which meant, Meta (change) and pherein (carry, code) (Levine, 2005).

The metaphors are information used to make situations understandable regarding conditions that individuals cannot realize as concrete and when phenomena become complicated (Yob, 2003). This is an important tool for organizing information in a planned manner and revealing ideas that individuals have (Clarken, 1997). In other words, metaphor is a way of understanding and perceiving the world (Morgan, 1998). Metaphor is also defined as establishing a relationship between two different phenomena and reflecting a different mental scheme on the existing mental scheme (Saban, 2009). If a picture is equivalent to 1000 words, a metaphor is equal to 1000 times the effect of a picture on humans. Moreover, while the picture expresses only certain phenomena stably, a metaphor draws the mental framework of this phenomenon (Shuell, 1990). While Lakoff and Johnson (2005) have described metaphors as elements that help individuals for perception the world. In addition, they expressed to make sense of one type of thing, according to the characteristics of another kind. Additionally, it is stated that metaphor is especially used for revealing the individual's perceptions (Alger, 2009; Cerit, 2008; Guerro & Villamil, 2002; Sanchez et al., 2000). Every vital activity in the world uses DNA as genetic material. A DNA molecule can contain many genes that encode proteins and act as heredity units. All genes that a eucaryote cell has — about 21,000 in humans — are placed in structures, located in the nucleus called chromosomes (Simon, 2015). The conceptual categories for DNA-Gene-Chromosome concepts are more than one. At the same time, the subject of genetics involving these concepts is one of the areas that are difficult to learn and teach in a science-training program (Lewis & Wood–Robinson, 2000; Tsui & Treagust, 2007). Since metaphors activate the teaching-learning process, they establish communication between the known and unknown concepts (Botha, 2009). If the individuals, who received an education, were provided with an accurate understanding of separation or association of biological concepts, mixing concepts would have been reduced significantly. Indeed, the use of determined metaphoric perceptions in concept teaching facilitates learning. The function of metaphors is a kind of communication tool that supports this issue (Steger, 2007). Furthermore, the metaphors in concepts that cannot be thought of or have a learning difficulty, should have a high impact and persistence on learning.

Within the framework of the literature review, leading scholars and respective areas in determining metaphors of biological concepts are examined to recognize whether the study was conducted previously, in order not to overlap studies. In this context, the following subjects were reviewed as tracks: Concept of the genome (Konopka, 2002); the concept of biological systems (Neuman, 2005); the concept of the gene (Vennille et al., 2006); concepts of "greenhouse effect", "ozone layer", "acid rains" and "biodiversity" (Selvi, 2007); metaphors of Darwin's book "Origin of Species: Natural Selection" (Al-Zahrani, 2008); metaphors for concepts of "evolution, regeneration and adaptation" (Eilam, 2009); the concept of climate (Coşkun, 2010), the concept of greenhouse effect (Shepardson et al., 2011); the concept of synthetic biology (Hellsten & Nerlich, 2011); the concept of biology (Gürbüzoğlu et al., 2013; Harman & Çökelez, 2017; Ulukök et al., 2015; Yapıcı, 2015); the concept of nature (Kahyaoğlu, 2015); the concept of global warming (Emli & Afacan, 2017); the concept of evolution (Özbuğutu, 2018); and the concept of Biology Education Laboratory Course (Cengiz & Ekici, 2019). Apart from metaphors of biological concepts stated above, it is understood that metaphoric perceptions feed on cognitive levels of individuals, past experiences, and socio-cultural structures, as a part of further literature review (Bargh & Bandrollar, 1996).

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Research Purpose

This research has been conducted to reveal the science prospective teachers' metaphors perceptions about the concept of DNA-Gen-Chromosome, to be according to the class levels and different university factors. On the other hand, the purpose of this research was in order to introduce the meaning of DNA-Gene-Chromosome to students with metaphors, rather than defining its meaning. The following research questions have been formulated in this regard accordingly.

1. What are the prospective teachers' metaphors about the concept of DNA-Gen-Chromosome?
2. Under which conceptual categories can these metaphors fall, in terms of common features?
3. What are the common categories of prospective teachers' DNA-Gen-Chromosome concepts in different university variables?

Research Methodology

General Background

The study was carried out with phenomenon (phenomenography) design, which is one of the qualitative research approaches. Phenomenography is a qualitative research approach that has been designed to find out peoples' qualitatively different experiences of the world in terms of categories of descriptions. (Marton, 1981, 1986). The phenomenon of science design (phenomenology) created a suitable research ground for studies aiming to examine phenomena that could not pick up the exact meaning of it. At the same time, it put forward the phenomenon, which was known without in-depth knowledge in various ways, such as case, experience, perception, and orientation (Yıldırım & Şimşek, 2008). Also, it was a research design that experienced the phenomenon described, and the philosophy and psychological infrastructure were built on bases (Creswell, 2014). It focused on how individuals perceived a specified phenomenon, how it was described, how they felt about it, how they talked about it (Patton, 2014).

Sample

Two State Universities were selected from the east (Eastern Anatolia Region) and north (Blacksea Region) of Turkey. Two universities were chosen because of the convenience sampling. They were defined as "A" and "B" University, respectively, for the Fall Semester 2017-2018, as the study group. The sample consisted of a total of 326 students. These two universities were chosen because they have the same course content, and their entrance scores are the same. The reason for preference is to determine the common metaphorical perceptions of pre-service teachers who study at different universities with the same education and the same level, towards the same concepts. The number of students was chosen on a voluntary basis because sample is formed in this way. These students were in their 1st, 2nd, 3rd, and 4th classroom level of university in the Science Education Department of Education Faculties. These individuals are considered to become science prospective teachers [please refer to Table 1 for detailed information].

The sample was determined with the help from easily accessible sampling methods, as this is a method that aids the researcher to be close and easily accessible when determining the sample (Yıldırım & Şimşek, 2011).

Table 1
Data Regarding the Prospective Teachers' University and Classroom Levels

Variable (University)	Variable (Classroom Levels)			
	1. Year	2.Year	3. Year	4.Year
East (Eastern Anatolia) Region (A University)	67	10	67	33
North (Black sea) Region (B University)	46	42	23	38
Sub-Total	113	52	90	71
Total	326			

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Data Collection

The data were collected through metaphors. In metaphors studied, semi-structured interview forms were one of the most preferred data collection tools (Pishghadam & Pourali, 2011). Yıldırım and Şimşek (2011) stated that metaphor could not adequately reveal the descriptive and visual power of metaphor itself. Thus, the question "why" or "how" must be asked to reveal the descriptive and visual power of metaphors. In this context, a semi-structured interview form was prepared for all prospective teachers who constituted the sample group. This form contains information such as follows: DNA is like ……………… because ………………………; The gene is like ……………… because ……………………… ....; The chromosome is like ………………, because …………………. Consequently, these sentences are used in the respective form.

Students were asked to only reflect on a single metaphor, for these concepts. Also, for the part that evokes, they were requested to complete the sentence by providing explanations after the word "because." In addition, prospective teachers were asked to write down which university they were in and their class. The pilot application of the form was prepared for the research. It was tested with the participation of 35 science teachers who had been graduated from various universities. Considering the obtained results from this application, the form was rearranged, and the time to be allocated to the group was identified, accordingly. Upon distribution of the upgraded forms, the metaphor phenomenon was explained to the students, and several examples were delivered to reveal the mental images. Besides, the justification for simulation between the source and subject was provided. 20 minutes were allocated to each student to complete the form. Thus, the metaphors and explanations that constitute the research data were obtained.

Data Analysis

The descriptive content analysis of qualitative research technique was used for "analysis and interpretation" of data. Also, the metaphors with certain common features were compiled under certain collective conceptual categories. The data analysis consists of two parts: metaphor analysis (Moser, 2000) and content analysis (Yıldırım & Şimşek, 2008). The content analysis is defined as a "systematic application where some words of a text summarized with smaller content categories with coding are based on certain rules" (Büyüköztürk, 2011). The metaphor analysis was conducted step by step (Moser, 2000).

The following stages were identified:

1. Screening Phase
2. Compilation and Category Development Phase
3. Validity and Reliability Phase

1. Screening Phase

The filled-in papers by prospective teachers were examined individually. Their metaphors were determined and placed in alphabetical order. Forms that were missing subject, resource section, or not metaphors, along with, forms that were metaphors, but descriptions did not match were excluded from the examination part (n:9). Additionally, forms that metaphoric perceptions or justifications for the DNA-Gene-Chromosome concepts were compared and ignored from analysis (n:4). The terms such as (S1,3.) in parentheses were interpreted as 1st student of 3rd grade in the samples. These were written by prospective teachers; in which, the writings were reported identically.

2. Compilation and Category Development Phase

The categories were determined to be in line with the common characteristics of metaphors in the compiled data for the identified concepts. These categories were identified as shape, function, feature, and content. The prospective teachers and metaphors were marked under these categories and used as codes.

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3. Validity and Reliability Phase

To ensure validity;

1. The process of creating common categories from all metaphors was explained in detail.
2. All metaphors were obtained as a result of the sorting process, as indicated in the table in the findings section.
3. The data were recorded by prospective teachers and kept without any additions. In research reporting, collecting, and citing the participants' statements without addition was stated as a measure that increases the validity (Yıldırım & Şimşek, 2011).

To ensure reliability;

Categorization of metaphors was consulted with expert opinion in a semi-structured document that was written by prospective teachers. A biologist trainer expert issued a document with written metaphors and two papers. The expert was asked to place metaphors in categories that were made by the researcher or expert for comparison. The number of consensus and disagreement was determined, and reliability was calculated by the formula of Miles & Huberman (1994; 64).

Reliability = Consensus / (Consensus + Disagreement) X 100

The average reliability between expert and researcher was determined as 94%. In qualitative research, it stated that if the consistency between evaluations of expert and researcher is 90% and above, it provides reliability (Miles & Huberman, 1994). Hence, the result showed the level of reliability that had been reached in the research.

In the last stage, the number of teacher candidates representing each metaphor and category were calculated as frequency (*f*) and percentage (%). The obtained data were presented in tables and interpreted, accordingly.

Research Results

Metaphoric perceptions of the science-prospective teachers who participated in the study of DNA-Gene-Chromosome concepts were shown in tables. The frequencies and percentages were formed in relevant codes, and categories were indicated in the tables. The prospective teachers provided answers that created codes and categories. These were submitted as a quote in the following section, after the data tables. Upon examining the obtained data, it was understood that a total of 313 metaphors were collected from 326 participants, regarding DNA-Gene-Chromosome concepts. Among metaphors, a total of 11 common metaphorical perceptions were determined in A and B universities, in the category of DNA concept as related to the shapes (3), function (3), feature (2), and content (3). There was no common metaphoric perception in the category of the gene for the shapes. Yet, 14 common metaphoric perceptions were identified respectively for function (4), feature (6), and content (4). In the category of the concept of chromosomes, a total of 9 common metaphorical perceptions were determined for the shapes (7), function (1), and feature (1), despite lack of content common metaphoric perceptions. A total of 34 common perceptions were identified from 313 metaphoric perceptions. And 279 metaphors were differed according to the class and university variables.

Table 2
Total Valid Metaphors of the Prospective Teachers on DNA-Gene-Chromosome Concepts

	Category	Variable (university)	
		A University	B University
DNA	Shape	7	12
	Function	9	14
	Feature	5	19
	Content	9	12
	TOTAL	30	57

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	Category	Variable (university)	
		A University	B University
GENE	Shape	4	4
	Function	13	13
	Feature	26	30
	Content	26	18
	TOTAL	69	65
CHROMOSOME	Shape	13	18
	Function	11	8
	Feature	7	13
	Content	12	10
	TOTAL	43	49

Table 3
Perceptions of the Prospective Teachers in the Category of Shape for the Concept of DNA

Category	Variable (University)	Codes	1.Class		2.Class		3. Class		4.Class		Total f	%
			Student Codes	f	Student Codes	f	Student Codes	f	Student Codes	f		
SHAPE	A University	Ladder	$S_{8,14,42,48,49,50}$	6	$S_{1,3,5,6,7,8}$	6	$S_{1,3,4,6,7,8,9,11,12,3,17,18,19,20,21,23,24,25,26,28,29,30,32,34,35,37,42,43,44,45,47,48,49,50,51,54,55,57,58,59,60,61,62,64,65}$	45	$S_{6,7,8,10,11,14,20,24,28,29,30,31}$	12	69	87
		Bullbrier	$S_{18,64}$	2			S_{52}	1			3	4
		Earphone	S_{25}	1							1	1
		Snake	S_{55}	1			S_{38}	1			2	3
		Macaroni					S_{10}	1			1	1
		Minaret					$S_{14,53}$	2			2	3
		Confetti	S_{35}	1							1	1
	TOTAL										79	100
	B University	Macaroni	S_{19}	1	S_{10}	1					2	4
		Cylinder	S_{20}	1							1	2
		Ladder	$S_{21,22,23,25,29,31,33,35}$	8	$S_{14,15,17,27,28,34,37,39,40}$	9	$S_{1,3,7,8,11,13,17,23}$	8	$S_{3,7,13}$	3	20	43
		Plaited Cheese	$S_{39,40}$	2							2	4
		Bow			S_{5}	1	S_{9}	1			2	4
		Ice Cream			S_{16}	1					1	2
		Bullbrier			S_{30}	1	$S_{14,19}$	2	$S_{2,4,8,9}$	4	7	15
		Piece							S_{3}	1	1	2
		Ball							S_{19}	1	1	2
		Chair					$S_{2,16,21}$	3	$S_{10,14,15,19}$	4	7	15
		Thread					S_{6}	1	$S_{3,28}$	2	3	6
	TOTAL										47	100

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According to both universities (A and B universities) participants, the prospective teachers' common metaphorical perceptions of DNA in the Shape category were macaroni, ivy, and ladder [Table 3]. Besides, although the frequencies were different, the prospective teachers used common shapes.

Table 4
Perceptions of the Prospective Teachers in the Category of Function for the Concept of DNA

Category	Variable (University)	Codes	1.Class		2. Class		3. Class		4.Class		Total f	%
			Student Codes	F	Student Codes	F	Student Codes	F	Student Codes	f		
FUNCTION	A University	Human Skeleton	S_7	1							1	7
		Toy block	S_2	1							1	7
		Jigsaw	$S_{6,32}$	2			S_{15}	1	S_9	1	4	29
		Button	S_{10}	1							1	7
		Photocopier	S_{21}	1							1	7
		Sibling	$S_{53,67}$	2							2	14
		Key-Lock	S_{54}	1							1	7
		Pedestrian					S_{66}	1			1	7
		Manager							S19,22	2	2	14
	TOTAL										14	100
	B University	Driver			S_3	1					1	4
		Key-Lock			S_{25}	1			S_1	1	2	8
		Teacher							S_{21}	1	1	4
		Seed			$S_{3,29}$	2	S_9	1			3	13
		Processor					S_1	1			1	4
		Road					S_5	1			1	4
		Board of Directors							S_{28}	1	1	4
		Sand							S_{29}	1	1	4
		Point							S_{31}	1	1	4
		Lover	S_8	1	$S_{7,20}$	2					3	13
		Book	S_{12}	1							1	4
		Jigsaw	S_{14}	1	S_{26}	1					2	8
		Brain			S_{23}	1	S_{10}	1			2	8
		Manager							$S_{12,18,21,37}$	4	4	17
	TOTAL										24	100

The common metaphorical perceptions of prospective teachers, in the function of DNA category, resulted in the metaphors 'jigsaw', 'key-lock' and 'manager' which were proven to be in line with the variable. Also, the frequencies of common metaphorical perceptions consisted of high metaphoric perceptions [Table 4].

The samples of prospective teachers were pointed out as follows;
"DNA is like a human skeleton. Because, in the absence of DNA, sequences cannot balance" (A, 1., S7).
"DNA is like a copier. Because it can match with the same one" (A, 1., S21).

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Table 5
Perceptions of Prospective Teachers in the Category of Feature for the Concept of DNA

Category	Variable (University)	Codes	1.Class		2. Class		3. Class		4.Class		Total f	%
			Student Codes	f	Student Codes	F	Student Codes	f	Student Codes	f		
FEATURE	A University	Zipper	$S_{1,5,11,15,19,24,26,27,62}$	9							9	69
		Branch	S_{34}	1							1	8
		Mother					S_{2}	1			1	8
		Cash Card					S33	1			1	8
		Fingerprint					S_{22}	1			1	8
	TOTAL										13	100
	B University	Jigsaw					$S_{4,12,20}$	3			3	8
		Class			S_{2}	1					1	3
		Zipper	$S_{11,15}$	2	$S_{4,31}$	2					4	10
		Personality	S_{11}	1	S_{38}	1	S_{7}	1	S_{11}	1	4	10
		Human			S_{6}	1					1	3
		Computer	$S_{33,44}$	2					$S_{17,32,37}$	3	5	13
		Telephone			S_{8}	1					1	3
		Atomic							$S_{10,12,14,19}$	4	4	10
		Husband-Wife			S_{12}	1					1	3
		Flash Disk			S_{18}	1					1	3
		Mother			S_{19}	1					1	3
		Word	S_{13}	1							1	3
		Code			S_{21}	1					1	3
		Password			S_{38}	1					1	3
		Brain			S_{35}	1	S_{16}	1	S_{36}	1	3	8
		Cufflink							S_{3}	1	1	3
		Ant							S_{15}	1	1	3
		Lock	$S_{3,4,10}$	3	S_{42}	1					4	10
		USB	S_{5}	1							1	3
	TOTAL										39	100

It was noted, the prospective teachers' common metaphoric perceptions in the feature category of DNA zipper and mother were in line with the university variable [Table 5].

The samples of the prospective teachers were stated as follows:

"DNA is like a zipper. Because it can divide into two and match itself" (A, 1., S1).

"DNA is like a mother. Because it carries viability functions and all instructions applicable to biological developments" (A, 3., S2).

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Table 6
Perceptions of the Prospective Teachers in the Category of Content for the Concept of DNA

Category	Variable (University)	Codes	1.Class		2. Class		3. Class		4.Class		Total f	%
			Student Codes	f	Student Codes	f	Student Codes	f	Student Codes	f		
CONTENT	A University	Wagon	S_{3}	1							1	5
		Thread	S_{4}	1							1	5
		Family	S_{39}	1							1	5
		Water	$S_{45,46}$	2							2	10
		Password	S_{41}	1							1	5
		Seed	S_{63}	1							1	5
		Chain	$S_{13,16,29,30,31,37,50,60,61}$	9			S_{56}	1	$S_{21,26}$	2	12	57
		FBI					S_{5}	1			1	5
		Library					S_{27}	1			1	5
	TOTAL										21	100
	B University	Thread	$S_{1,30,34}$	3	S_{41}	1					4	12
		Chain	$S_{2,16,17,38,41}$	5	$S_{24,29}$	2					7	21
		World	S_{27}	1					$S_{25,29}$	2	3	9
		House							S_{33}	1	1	3
		Pip			S_{36}	1	S_{8}	1			2	6
		Password	S_{28}				$S_{15,23}$	2	S_{13}	1	3	9
		Universe					S_{2}	1			1	3
		Room					S_{10}	1	$S_{18,26}$	2	3	9
		Flash Disk					S_{14}	1	$S_{35,38}$	2	3	9
		Class							$S_{23,27}$	2	2	6
		School							S_{25}	1	1	3
		Kite			S_{1}	1			$S_{11,17,23}$	3	4	12
	TOTAL										34	100

According to A and B University participants, it was noted that the prospective teachers' common metaphoric perception and codes with the highest frequency were 'chain'. Also, thread and password were common at different frequencies and in line with university variable, as common metaphoric perceptions [Table 6].

The samples of the prospective teachers are mentioned as follows;

"DNA is like the train wagons. Because deoxyribose sugar connects to phosphate as the phosphate connects a kind of base" (A, 1., S3).

"DNA is like a chain. Because genes keep together in DNA formation" (A, 1., S13).

"DNA is the FBI. Because it hides all the information and secretly turns business. It carries all the living creatures' genetic activities" (A, 3., S5).

"DNA resembles a kite tail. Because every piece on the tail represents the nucleotide" (G,2, S1).

"DNA is like a necklace chain. Because there are nucleotides on it, like a thread. It is like a chain since it is two-sided" (G,2, S24).

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Table 7
Perceptions of the Prospective Teachers in the Category of Shape for the Concept of Gene

Category	Variable (University)	Codes	1.Class		2. Class		3. Class		4.Class		Total f	%
			Student Codes	f	Student Codes	f	Student Codes	f	Student Codes	F		
SHAPE	A University	Pip	$S_{11,15}$	2							2	29
		Bonbon	S_{35}	1							1	14
		Toothpick					$S_{7,8}$	2			2	29
		Grit					$S_{3'52}$	2			2	29
	TOTAL										7	100
	B University	Piece					S_{3}	1			1	20
		Ball					S_{19}	1			1	20
		Cross (X)	S_{41}	1							1	20
		Ladder			$S_{39,42}$	2					2	40
	TOTAL										5	100

Category	Variable (University)	Codes	1.Class		2. Class		3. Class		4.Class		Total f	%
			Student Codes	f	Student Codes	f	Student Codes	f	Student Codes	F		
SHAPE	A University	Pip	$S_{11,15}$	2							2	29
		Bonbon	S_{35}	1							1	14
		Toothpick					$S_{7,8}$	2			2	29
		Grit					$S_{3'52}$	2			2	29
	TOTAL										7	100
	B University	Piece					S_{3}	1			1	20
		Ball					S_{19}	1			1	20
		Cross (X)	S_{41}	1							1	20
		Ladder			$S_{39,42}$	2					2	40
	TOTAL										5	100

The prospective teachers did not have common metaphoric perceptions in the category of the shape of the gene concept in line with the university variable [Table 7].

The samples of the prospective teachers are indicated as follows:

"The gene is like the fruit pip. Because it is very small like fruit pips. It is formed by combining of millions" (A,1, S11).

"The gene is like a bonbon. Because they have different inheritance features, but their structures are the same" (A,1, S35).

"The gene resembles a toothpick. Because it is in the form of a long or short stick" (A,3, S7).

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Table 8
Perceptions of the Prospective Teachers in the Category of Function for the Concept of Gene

Category	Variable (University)	Codes	1.Class		2. Class		3. Class		4.Class		Total f	%
			Student Codes	f	Student Codes	f	Student Codes	f	Student Codes	F		
FUNCTION	A University	Key-Lock	S_1	1							1	4
		Body	$S_{3,18}$	2	S_3	1					3	11
		Jigsaw	$S_{7,10,13}$	3					$S_{15,27}$	2	5	19
		Clip	S_8	1							1	4
		Magnet	S_9	1							1	4
		Ant	S_{25}	1							1	4
		Password	$S_{53,54}$	2					$S_{12,19,26,31}$	4	6	22
		Soil	S_{61}	1							1	4
		Lorry Driver					S_{13}	1			1	4
		Ladder	S_{12}	1			S_{27}	1			2	7
		Point			S_1	1	S_{38}	1			2	7
		Solitaire					S_{59}	1			1	4
		Corn					$S_{61,62}$	2			2	7
	TOTAL										27	100
	B University	Seed					S_9	1			1	6
		Key-Lock	S_{13}	1					S_1	1	2	13
		Teacher							S_{21}	1	1	6
		Processor					S_1	1			1	6
		Road					S_5	1			1	6
		Board of Directors					S_2	1	S_{24}	1	2	13
		Sand							S_{29}	1	1	6
		Point							S_{31}	1	1	6
		Magnet	S_{20}	1							1	6
		Password	S_{46}	1							1	6
		Father			S_{11}	1					1	6
		Bullbrier			$S_{23,41}$	2					2	13
		Tree			S_{34}	1					1	6
	TOTAL										16	100

The metaphoric perceptions of the prospective teachers with regards to the concept of gene in the common category of function were observed as key-lock, magnet, point, and password to be in line with the university variable [Table 8].

The samples of the prospective teachers are mentioned as follows:

"Gene is like a key lock. Because it can be connected, and has dent and bulge" (A,1, S1).

"Genes are like organs of the body. Because each of them is interconnected" (A,1, S3).

"Gene is like jigsaw pieces. Because in case of gene deficiency, it can lead to major negativities" (A,1, S7).

"The gene is like a paper clip. Because genes (A, T, G, S) are being connected with each other" (A,1, S8).

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"Gene is like an organ. Because every organ has a way of functioning, and a task" (A,1, S18).
"Gene resembles ants. Because it's small and useful, like an ant" (A,1, S25).
"Gene is like phone's password. Because it cannot be opened without clearing the password" (A,1, S53).
"Gene is like a point. Because it is located on chromosomes and special to it" (A,2, S1).
"The gene is like the lorry driver. Because it transports certain items from one place to another" (A,3, S13).
"The gene is like a rotating ladder. Because its spiral structure and connecting Adenin-Timin form the gene steps" (A,3, S27).

Table 9
Perceptions of the Prospective Teachers in Category of Feature for the Concept of Gene

Category	Variable (University)	Codes	1.Class		2. Class		3. Class		4.Class		Total F	%
			Student Codes	f	Student Codes	f	Student Codes	f	Student Codes	f		
FEATURE	A University	Identity	$S_{2,5}$	2			$S_{6,9,14,20}$	4	$S_{28,29,32}$	3	9	15
		Type of food	S_{16}	1							1	2
		Fingerprint	$S_{17,27}$	2			$S_{24,25,26}$	3	$S_{6,13}$	2	7	12
		Button	S_{19}	1							1	2
		Feeling	S_{39}	1							1	2
		Memory	S_{62}	1							1	2
		Root			S_{5}	1					1	2
		Brain					$S_{3,31}$	2	S_{14}	1	3	5
		Microchip					S_{4}	1			1	2
		Reign					$S_{5,63,64}$	3			3	5
		Chain					$S_{11,30,32}$	3			3	5
		Draw					S_{18}	1			1	2
		Culture					$S_{22,53}$	2			2	3
		Computer					S_{28}	1			1	2
		Processor					S_{33}	1			1	2
		Traditions					S_{36}	1			1	2
		Family Tree					S_{37}	3			3	5
		Fruit					S_{39}	1			1	2
		Vehicle Engine					S_{44}	1			1	2
		Head of Family					$S_{45,46}$	2			2	3
		Information					S_{50}	1			1	2
		Historical Artifact					$S_{65,66,67}$	3			3	5
		Ant							S_{3}	1	1	2
		Bead							$S_{10,11}$	2	2	3
		Password							$S_{1,12,20,23,31,33}$	6	6	10
		Atomic	S_{58}	1			S_{23}	1			2	3
	TOTAL										59	100

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Category	Variable (University)	Codes	1.Class		2. Class		3. Class		4.Class		Total F	%
			Student Codes	f	Student Codes	f	Student Codes	f	Student Codes	f		
	B University	Personality	S_{11}	1	S_{38}	1	S_{7}	1	S_{11}	1	3	3
		Computer	$S_{33,34,38}$	3					$S_{17,32,37}$	3	6	9
		Atomic			$S_{10,24}$	2			$S_{10,12.14,19}$	4	6	9
		Brain			S_{35}	1	$S_{15,16}$	2	$S_{35,36}$	1	4	6
		Cufflink							S_{3}	1	1	2
		Ant							S_{15}	1	1	2
		Fingerprint	$S_{1,5}$	2	$S_{6,20}$	2					4	6
		Human	$S_{3,6,7,16,19,27}$	6	$S_{17,22}$	2					8	12
		Stone	S_{9}	1							1	2
		Pin code	S_{18}	1							1	2
		Salt	S_{31}	1							1	2
		Sugar	S_{32}	1							1	2
		Chameleon	S_{42}	1							1	2
		House	S_{44}	1					S_{33}	1	2	3
		Chair			S_{1}	1					1	2
		Flag			S_{2}	1					1	2
		Word			S_{4}	1					1	2
		Planet			$S_{15,16}$	2					2	3
		Plastic Bottle			$S_{18,32}$	2					2	3
		Rainbow			S_{20}	1					1	2
		Case			S_{25}	1					1	2
		Heritage			S_{27}	1					1	2
		Atatürk Portrait			S_{28}	1					1	2
		Pip			S_{36}	1	S_{8}	1			2	3
		Password					$S_{15,23}$	2	S_{13}	1	3	3
		Universe					S_{2}	1			1	2
		Room					S_{10}	1	$S_{18,26}$	2	3	4
		Flash Disk					S_{14}	1	$S_{35,38}$	2	3	4
		Class							$S_{23,27}$	2	2	3
		Manager							S_{25}	1	1	2
	Total										66	100

The common metaphorical perceptions of prospective teachers, in the feature category of the concept of Gene, are computer, ant, password, atomic, brain, and fingerprint, per university variable [Table 9].

The samples of the prospective teachers are stated as follows:

"Gene is a small identity. Because it has characteristics of an individual" (A,1, S_2).
"Gene is like a fingerprint. Because genes are different and unique" (A,1, $S_{17.}$)
"Gene is like memory. Because it is tiny, and retains a lot of information" (A,1, S_{62}).
"Gene is like the brain. Because it stores every information" (A,3, S_3).
"Gene is like a microchip. Because it carries information like a gene on itself" (A,3, S_4).
"Gene looks like a striped sweater's lines. Because genes are lined up on the chromosome as dots" (A,3, S_{18}).

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"Gene is like culture. Because it has traces of everybody's culture" (A,3, S_{22}).
"Gene is like a vehicle engine. Because, if engines function in old vehicles, the next generation shall be solid, accordingly" (A,3, S_{44}).
"Gene is like the head of the family. Because information on features of the whole body is included in the gene. It manages the body" (A,3, S_{45}).
"Genes are like ants in the soil. Because there are too many" (A,4, S_3).
"Gene is like a chair. Because it carries one person" (G,2, S_1).
"Gene is like a flag. Because it represents an individual country" (G,2, S_2).

Table 10
Perceptions of the Prospective Teachers in the Category of Content for the Concept of Gene

Category	Variable (University)	Codes	1.Class		2. Class		3. Class		4.Class		Total f	%
			Student Codes	f	Student Codes	f	Student Codes	f	Student Codes	f		
CONTENT	A University	Seed	$S_{6,22}$	2			$S_{12,56}$	2			4	9
		Trefoil	S_{14}	1							1	2
		CD	$S_{21,28}$	2							2	4
		Code	$S_{24,64}$	2					S_{27}	1	3	6
		Star	$S_{32,34}$	2							2	4
		Snowflake	S_{33}	1					S_7	1	2	4
		Rainbow	S_{41}	1							1	2
		Pollen	S_{46}	1							1	2
		Yarn	S_{49}	1			S_{17}	1			2	4
		Sand	S_{56}	1							1	2
		Sea	S_{60}	1							1	2
		Fruit			S_6	1	S_{60}	1			2	4
		Mainboard			S_8	1					1	2
		Rosary					$S_{1,21}$	2			2	4
		Identity Card					$S_{6,9,14,20}$	4	$S_{17,24,30}$	3	7	15
		Letter					S_{34}	1	S_{20}	1	2	4
		Report Card					S_{35}	1			1	2
		Name-Surname					$S_{42,49}$	2			2	4
		Knot					$S_{47,55}$	2			2	4
		Salad					S_{48}	1			1	2
		Tree					$S_{51,58}$	1	S_9	1	2	4
		Moneybox							S_2	1	1	2
		Library							S_4	1	1	2
		Solar System							S_5	1	1	2
		Class							S_{18}	1	1	2
		Encyclopedia							S_{28}	1	1	2
	TOTAL										47	100

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B University	House							S_{33}	1	1	3
	Pip			S_{36}	1	S_{8}	1			2	5
	Password					$S_{15,23}$	2	S_{13}	1	3	8
	Universe					S_{2}	1			1	3
	Room					S_{10}	1	$S_{18,26}$	2	3	8
	Flash Disk					S_{14}	1	$S_{35,38}$	2	3	8
	Class							$S_{23,27}$	2	2	5
	Manager							S_{25}	1	1	3
	Flower	S_{2}	1							1	3
	Snowflake	$S_{4,8,12,15}$	4	$S_{12,14}$	2					6	17
	Fruit	$S_{10,14}$	2							2	5
	Raisin Pie	S_{26}	1							1	3
	Chain	S_{30}	1	S_{40}	1					2	5
	Family	$S_{37,43}$	2							2	5
	Proverb	S_{40}	1							1	3
	Seed			$S_{3,29}$	2					2	5
	Figure			S_{9}	1					1	3
	Teacher			$S_{33,37}$	2					2	5
TOTAL										36	100

Common metaphorical perceptions of prospective teachers in the content category of the concept of Gene is class, seed, snowflake, and fruits, per university variable (Table 10).

Samples of the prospective teachers are indicated as follows:

"Gene looks like a seed. Because as genes are passing down from generation to generation, same plants come out, when seeds fall into the ground" (A,1, S22).
"Gene is like computer codes. Because each code determines a different feature" (A,1, S24).
"Gene is like stars. Because its size and shape are different" (A,1, S32).
"Gene is like snowflakes. Because every gene has a different shape" (A,1, S33).
"Gene is like a rainbow. Because colors of the rainbow are different. Genes are different as colors" (A,1, S41).
"Gene is like a colored spiral thread. Because it consists of many nucleotides" (A,1, S49).
"Gene is like rosary beads. Because nucleotides in the gene structure are lined up like rosary beads" (A,3, S1).
"Gene is like an identity card. Because it has everyone's features" (A,3, S6).
"Gene is like a letter. Because when keeping together, meaningful words are formed" (A,3, S34).
"Gene is like knots. Because knots form knitting as combined, while genes form a hereditary structure" (A,3, S47).
"Gene is like salad. Because it combines to "form a whole" from different vegetables" (A,3, S48).
"Gene is like a flower on a tree. Because it is located on the DNA" (A,3, S58).
"Gene is like a money box. Because it is full of information" (A,4, S2).
"Gene is like a library. Because it retains a lot of information" (A,4, S4).
"Gene is like a proverb. Because it passes down from generation to generation. The gene passes to young individuals" (G,1, S40).
"Gene is like a teacher. Because one can learn all features of the whole body from it" (G,2, S33).

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Table 11
Perceptions of the Prospective Teachers in the Category of Shape for the Concept of Chromosome

Category	Variable (University)	Codes	1.Class		2. Class		3. Class		4.Class		Total f	%
			Student Codes	f	Student Codes	f	Student Codes	f	Student Codes	f		
SHAPE	A University	Latch	$S_{1,11,15}$	3			$S_{10,17,37}$	3			6	11
		Ladder	$S_{3,7,21}$	3							3	5
		Trefoil	$S_{5,22}$	2	S_{6}	1	$S_{31,57,58}$	3			6	11
		Cross (X)	$S_{8,9}$	2			$S_{2,45}$	2			4	7
		Scissors	$S_{18,50}$	2			S_{7}	1	$S_{13,24,30}$	3	6	11
		Butterfly	$S_{26,62}$	2			$S_{13,14,18,19,25,30,32,42,43,44,48,49,54,59,61,62}$	16	S_{20}	1	19	35
		Braid	$S_{60,61}$	2							2	4
		Bow-tie	S_{19}	1			S_{27}	1			2	4
		Worm			S_{1}	1	S_{50}	1			2	4
		Curly Hair					S_{26}	1			1	2
		Kangaroo					S_{28}	1			1	2
		Horn					$S_{47,55}$	2			2	4
		Leaf					S_{52}	1			1	2
	TOTAL										55	100
	B University	Latch	$S_{1,2,12}$	3			S_{14}	1	$S_{11,16}$	2	6	14
		Butterfly	$S_{14,22,23,30,32,39}$	6					S_{14}	1	7	16
		Scissors	$S_{16,46}$	2	S_{12}	1					3	7
		Pincers	S_{34}	1							1	2
		Sausage	S_{35}	1							1	2
		Spider Web	$S_{37,42,43}$	3							3	7
		Mosquito	S_{40}	1							1	2
		Ladder			$S_{11,32,41}$	3					3	7
		Bow-tie			S_{13}	1					1	2
		Cartoon Character			S_{18}	1					1	2
		Cross (X)			S_{29}	1	$S_{6,13,15,16}$	3			4	9
		Bullbrier			S_{38}	1	$S_{11,22}$	2	S_{24}	1	4	9
		Twin							$S_{13,18}$	2	2	5
		Thread							S_{9}	1	1	2
		Trefoil					$S_{12,20}$	2			2	5
		Chain					S_{4}	1			1	2
		Sandglass							S_{34}	1	1	2
		Branch							$S_{7,26}$	2	2	4
	TOTAL										44	100

According to university variable, common metaphorical perceptions of prospective teachers in the category of the shape of chromosome concept is latch, butterfly, cross (X), bowtie, trefoil, ladder, and scissors [Table 11].

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The samples of the prospective teachers are expressed as follows:

"Chromosome is like a latch. Because latch's clamp is like centromere in chromosome" (A,1, S11).
"Chromosomes are like a ladder. Because every step has a line" (A,1, S3).
"Chromosome is like a ladder. Because there are separate lines in each step" (A,1, S7).
"Chromosome is like a worm. Because it can move like a worm and may get longer" (A,2, S1).
"Chromosome is like curly hair. Because it looks like its structure" (A,3, S26).
"Chromosome is like a kangaroo. Because front legs are short and back legs are long" (A,3, S28).
"Chromosome is like sausage divided into four. Because it is similar in shape" (G,1, S35).
"Chromosome is like a mosquito. Because its wings look like chromosomes" (G,1, S40).

Table 12
Perceptions of the Prospective Teachers in the Category of Function for the Concept of Chromosome

Category	Variable (University)	Codes	1.Class		2. Class		3. Class		4.Class		Total f	%
			Student Codes	f	Student Codes	f	Student Codes	f	Student Codes	f		
FUNCTION	A University	X	$S_{16,37,39,42,48,49}$	6			$S_{1,15,21,64,65,66,67}$	7			13	48
		Photocopier	$S_{24,28}$	2							2	7
		Lover					S_{22}	1	S_{6}	1	2	7
		Two intersect-ing lines					S_{38}	1			1	4
		Elder sibling					S_{41}	1			1	4
		Friend					$S_{51,56}$	2			2	7
		Library							S_{4}	1	1	4
		Piece							S_{9}	1	1	4
		Twin							$S_{14,22}$	2	2	7
		Bus							S_{17}	1	1	4
		Toy							S_{19}	1	1	4
	TOTAL										27	100
	B University	Fruit Plate	S_{1}	1							1	6
		X	$S_{18,20,24,44}$	4	$S_{2,14,26,28}$	4					8	47
		Inseparable			$S_{1,33}$	2					2	12
		1 Digit			S_{5}	1					1	6
		Key-Lock			S_{42}	1					1	6
		Lover					S_{17}	1	S_{20}	1	2	12
		Compass							S_{10}	1	1	6
		Chip							S_{17}	1	1	6
	TOTAL										17	100

Common metaphorical perceptions of prospective teachers, according to university variable, in function category for the concept of chromosome, is the lover [Table 12].

The samples of the prospective teachers are explained as follows:

"Chromosome is like lovers. Because sometimes they are together and sometimes, they are separate from each other" (A,3, S22).

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"Chromosome is like a book. Because it explains how everything shall be" (A,4, S4).
"Chromosome is like grain. Because chromatids are formed as particles unite with each other" (A,4, S9).
"Chromosome is like fruit platter. Because, although it is separate, it makes sense when it is together" (G,1, S10).
"Chromosome is just valuable one. Because there is discomfort if too much or less" (G,2, S5).

Table 13
Perceptions of the Prospective Teachers in the Category of Feature for the Concept of Chromosome

Category	Variable (University)	Codes	1.Class		2. Class		3. Class		4.Class		Total f	%
			Student Codes	f	Student Codes	f	Student Codes	F	Student Codes	f		
FEATURE	A University	Sibling	$S_{27,38,54,55}$	4			$S_{9,20}$	2	S_5	1	7	50
		Husband-Wife	S_{35}	1							1	7
		Strap	$S_{53,67}$	2							2	14
		Case					S_{53}	1			1	7
		Lotus					S_{60}	1			1	7
		Bead							S_{10}	1	1	7
		Refugee Camp							S_{28}	1	1	7
	TOTAL										14	100
	B University	Link	S_4	1	S_3	1					2	7
		Sibling	$S_{3,6,7,17}$	4	$S_{6,14,17,21,27,40}$	5	S_{18}	1	$S_{4,28}$	2	11	38
		Mother	S_8	1					S_6	1	2	7
		Friend	S_{13}	1							1	3
		Military	S_{41}	1							1	3
		Glasses			S_{19}	1					1	3
		Swing Thread			$S_{20,23,25}$	3					3	10
		Seed							S_8	1	1	3
		Image			S_{31}	1					1	3
		Bag			S_{34}	1					1	3
		Sandglass			S_{36}	1					1	3
		Inseparable			S_{37}	1			$S_{2,19}$	2	3	10
		Latch			S_{39}	1					1	3
	TOTAL										29	100

Common metaphorical perceptions of prospective teachers, according to university variable in the feature category for the concept of chromosome, is sibling [Table 13].

The samples of the prospective teachers are stated as follows:
"Chromosome is like a human, and the paired chromosome is like husband and wife. Because it is paired with a chromosome that corresponds to it" (A,1, S35).
"Chromosome is like twins. Because they are similar in structure and are connected" (A,3, S20).
"Chromosome is like a case. Because it retains all the information" (A,3, S53).

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Table 14
Perceptions of the Prospective Teachers in the Category of Content for the Concept of Chromosome

Category	Variable (University)	Codes	1.Class		2. Class		3. Class		4.Class		Total f	%
			Student Codes	f	Student Codes	f	Student Codes	f	Student Codes	f		
CONTENT	A University	Child	S_{10}	1							1	8
		Cable	S_{13}	1							1	8
		Ribbon	S_{17}	1			S_{24}	1			2	15
		Abacus	S_{41}	1							1	8
		Atomic	S_{45}	1							1	8
		Encyclopedia	S_{63}	1							1	8
		Flash Disk	S_{64}	1							1	8
		Auto Part			S_3	1					1	8
		Body			S_5	1					1	8
		Star			S_7	1					1	8
		Fruit					S_{12}	1			1	8
		Chain							S_{27}	1	1	8
	TOTAL										13	100
	B University	Father-Mother	S_9	1							1	9
		Thread	S_{19}	1							1	9
		Molecule					S_7	1			1	9
		Family	S_{27}	1							1	9
		School			S_{10}	1			S_{23}	1	2	18
		Half Apple			S_{15}	1					1	9
		Raisin Pie			S_{35}	1					1	9
		Ship					S_8	1			1	9
		Train					S_9	1			1	9
		Storage					S_{10}	1			1	9
	TOTAL										11	100

According to the university variable, prospective teachers do not have a common metaphorical perception in the content category for the concept of chromosome [Table 14].

Samples of prospective teachers are indicated as follows:

"Chromosome is like a child in the family. Because the absence of a child led to great pain" (A,1, S10).

"Chromosome is like a surrounded cable. Because the formation of chromosome takes place by shortening and wrapping DNA" (A,1, S13).

"Chromosome is like an encyclopedia. Because it contains all the important information" (A,1, S64).

"Chromosome is like a star. Because there are nucleotides on it" (A,2, S7).

"Chromosome looks like two halves of an apple. Because parts represent chromosome threads, and core represents synapse" (G,2, S15).

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Discussion

Biology science examines many aspects of living and non-living creatures. These aspects include changes in the process starting from "time of existence up to the present." These are their distribution of nature and their development. They increase along with the structure (TDK, 2020). It is a discipline that reveals relationship levels of structures. These levels are interrelated in the human body (Zvi-Assafaf et al., 2013). They contain many abstract and complex concepts. It is significant to learn these concepts correctly and determine their relationships. At the same time, biology education in the Turkish education system is mostly oriented towards cognitive knowledge. Consequently, it requires implementation for effective information. The education life starts at the age of 5 and continues until the late '20s. During this educational process, while DNA-Gene-Chromosome concepts have been dealt with in various occasions, it emerges as concepts that cannot easily be solved. To challenge the concept complexity, metaphoric perceptions were used. In general, the usage of metaphor is a way of thinking that fits individuals' understanding of the world. In this respect, metaphor is a powerful resource that helps people understand and explain a highly abstract, complex, or theoretical phenomenon (Morgan, 1997). Therefore, this study validates the metaphoric perceptions of science prospective teachers, for DNA-Gene-Chromosome concepts. Also, it confirms that common metaphorical perceptions are in line with different variables that were identified to explain relationships.

As a result of this research, 326 science-prospective teachers produced 313 valid metaphors concerning DNA-Gene-Chromosome concepts. Thirty-four of these valid metaphors emerged as a common metaphoric perception. The remaining 279 metaphors differed, according to the class and university variables. It was ensured that common metaphoric perceptions in these different variables were compiled under specified conceptual categories. The points that draw attention, as a result of this research, indicated as follows:

First, prospective teachers used different metaphors to reflect their ideas concerning DNA-Gene-Chromosome concepts. Usage of metaphors is not a new technique in teaching. Metaphors are frequently used as teaching tools for subjects or concepts in educational research (Ben-Peretz et al., 2003; Botha, 2009). Also, metaphors are the reasons for being selected to reveal meanings that are being placed on the concept (Tynavcevic & Vaupot, 2009). It is understood that prospective teachers, who were the subject of this study group for DNA-Gene-Chromosome concepts, had continuously heard of the alleged concepts during their learning processes. Yet, they could not fully explore the relationship among the respective concepts (n=13).

Second, it was observed that prospective teachers had created more than one metaphor for these concepts, rather than creating certain metaphors. Weade and Ernst (1990) stated that "metaphors provide the opportunity to only explain part of the determined phenomenon." Also, it was understood that prospective teachers' metaphorical perceptions towards these concepts were limited with identified features. Another similar approach was mentioned in the study of Weade and Ernest. It indicates, "Metaphors represent only one part of the phenomenon." These relations are further supported by the statement expressing that "it does not explain the whole phenomenon (Weade & Ernst, 1990)." Also, it stated that metaphor was not identical to the phenomenon. It was only a symbol of the phenomenon, and only one phenomenon could be supported by multiple metaphors (Yob, 2003). Indeed, it explained that more than one metaphor was used for an individual phenomenon, in various studies that were conducted for the biological concepts (Al-Zahrani, 2008; Cengiz & Ekici, 2019; Coşkun, 2010; Eilam, 2009; Gürbüzoğlu et al., 2013; Harman & Çökelez, 2017; Hellsten & Nerlich, 2011; Kahyaoğlu, 2015; Konopka, 2002; Neuman, 2005; Vennille et al., 2006; Selvi, 2007; Ulukök et al., 2015; Yapıcı, 2015).

Third, based on different university or class variance, common metaphorical perceptions about DNA-Gene-Chromosome concepts were determined. While metaphors reveal ideas, it makes the ideas more permanent, understandable, and enlightening (Clarken, 1997). At the same time, metaphors reflect the thoughts and activities of those who used them to characterize certain concepts (Draaisma, 2007). Thus, as revealing perceptions of prospective teachers towards the concept of DNA-Gen-Chromosome, it was ensured to reflect the shapes of these concepts in minds, as well. Fourth, it is too difficult to overcome the complexity of the concepts of Biology, even if students have heard it many times. The used metaphors in daily life (Oxford et al., 1998), is a powerful mental tool that can be utilized to understand and explain concepts. These concepts are abstract, complex, and, not related to each other (Yob, 2003). Indeed, these concepts can be maintained for students by addressing different areas of intelligence, through relevant conceptual categories or codes. There might be many reasons, but one main reason is the concepts with a conceptual equivalent that could

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be related to being at the "microscopic level." Besides, it is possible to confuse the concepts that are invisible and related. Metaphors are reflections of facts in thought mechanisms of individuals concerning each other (Heywood, et al., 2002; Martinez et al., 2001). Meanwhile, metaphors enable the environment to keep the concepts in mind (Arslan & Bayrakçı, 2006; Goldstein, 2005). While individuals reflect accurate perceptions and interpretations in minds regarding the concepts. Also, they help to reflect their imagination and goals (Cornelissen et al., 2008; Lopez, 2007).

Conclusions

In this study, perceptions of prospective educators that loaded metaphorically related to DNA-Gen-Chromosome concepts, commonly used perceptions, according to different variables that had been determined. In fact, although there have been many studies in education concerning the determination of metaphoric perceptions. Yet, there has been no study to distinguish the concepts of DNA-Gene-Chromosome and relationship among them. Despite the different university and class variables, it has been observed that pre-service science teachers have common metaphorical perceptions of DNA-gene-chromosome concepts. The research results reflect the clues on "how science-prospective teachers perceive DNA-Gene-Chromosome concepts that have been obtained." Granting there were (326) students forming the study sample, the majority were not seen in the frequency percentages tables. On the other hand, the correct metaphorical perceptions concerning these concepts are limited. These limited parts provide a relationship between the subject and source. It shows that concepts are still mixed. This study was conducted only on prospective teachers who provided the correct subject-source relationship. Therefore, the frequency and percentages are less than the number of students.

Recommendations

The metaphors, obtained as a result of this research, may be used by the academicians who deliver lectures at the university level of education. Also, it can be used for high school teachers, who teach within the scope of biology lessons to plan the teaching process, shape the teaching-learning process, and measure and evaluate steps in the field of biology. Meanwhile, according to research data, metaphors reflecting DNA-Gene-Chromosome concepts, cover the hints on how science-prospective teachers perceive it. It can be used to determine the readiness of students with the same or different learning levels. Also, it reveals student's prior knowledge. The usage of determining metaphors by trainers may interest students' attention. It can enable students to distinguish between concepts, by bringing information to minds via terminology and practices. Thus, conceptual complexities can be eliminated. It can serve as a different teaching tool for biological terms, utilizing different techniques. The students' readiness for the course topic can be determined. Also, this research, which was conducted for the science-prospective teachers, may be used for the students that are studying other fields. It can also be utilized for high school students to challenge complex concepts. This research is not limited to only prospective teachers, but it can be applied in multidisciplinary fields.

This study exposed two university participants, one from the north and the other from the east of Turkey. Yet, it can be used for universities located in different regions, with various educational levels. At the macro level, metaphoric perceptions concerning the respective concepts or various concepts may be identified, as well. The biological concept metaphors set an example for each area included in the target content, in the educational process. Therefore, it can be used to perceive the terms DNA-Gene-Chromosome in all branches, starting from primary school up to higher education, using these concepts.

Although this study is only limited to concepts such as DNA-Gen-Chromosome, it creates examples for other concepts that are difficult to learn and relate to each other. This research result can aid in the determination of students' readiness levels for issues related to metaphors in new concepts, utilizing certain metaphors of these concepts.

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Turkey under the title of "Determining of Common Mental Images for DNA-Chromosome Concepts" while the data about the Gene Concepts submitted to the International Conference on Education in Mathematics, Science & Technology (ICEMST) took place on May 18 - 21, 2017 in Ephesus Kusadasi, Turkey under the title of " The Metaphoric Perceptions of Prospective Teachers on Gene Concepts".

References

Alger, C. L. (2009). Secondary teachers' conceptual metaphors of teaching and learning: Changes over the career span. *Teaching and Teacher Education*, *25*, 743-751. http://www.science direct.com/science/

Al-Zahrani, A. (2008). Darwin's metaphors revisited: Conceptual metaphors, conceptual blends, and idealized cognitive models in the theory of evolution. *Metaphor and Symbol*, *23*, 50-82.

Arslan, M., & Bayrakçı, M. (2006). Metaforik düşünme ve öğrenme yaklaşımının eğitim-öğretim açısından incelenmesi [Examination of metaphoric thinking and learning approach in terms of education]. *Millî Eğitim Dergisi [Journal of National Education]*, *171*, 100-108.

Banet, E., & Ayuso, E. (1999). Teaching genetics at secondary school: A strategy for teaching about the location of inheritance information. *Science Education*, *84*(3), 313–351.

Bargh, J. A., & Barndollar, K. (1996*). Automaticity in action: The unconscious as repository of chronic goals and motives.* Guildford Press.

Ben-Peretz, M., Mendelson, N., & Kron, F. W. (2003). How teachers in different educational contexts view their roles. *Teaching and Teacher Education*, *19*(2), 277-290.

Botha, E. (2009). Why metaphor matters in education. *South African Journal of Education*, 29, 431-444.

Büyüköztürk, Ş. (2011). *Sosyal bilimler için veri analizi el kitabı - istatistik, araştırma deseni, spss uygulamaları ve yorum* [Data analysis handbook for social sciences - statistics, research design, spss applications and interpretation, 15th Edition]. Pegem Academy.

Cengiz, İ. Y., & Ekici, G. (2019). Investigating metaphoric perceptions of biology teacher candidates on biology education laboratory course. *OPUS International Journal of Society Researches, 11*(18), 1218-1258.

Cerit, Y. (2008). Students, teachers and administrators' views on metaphors with respect to the concept of teacher. *The Journal of Turkish Educational Sciences*, *6*(4), 693-712.

Chuang, H. F., & Cheng, Y. J. (2003). A study on attitudes toward biology and learning environment of the seventh-grade students. *Chinese Journal of Science Education, 11*(2), 171–194.

Clarken, R. H. (1997). Five metaphors for education paper presented at the annual meeting of the American educational research association, Chicago.

Cornelissen, J. P., Oswick, C., Christenses, L.T., & Phillips, N. (2008). Metaphor in organizational research: Context, modalities and implications for research introduction. *Organization Studies, 29*(7), 8-22.

Coşkun, M. (2010). Metaphors (mental images) of high school students about "climate" concept. *Turkish Studies International Periodical for Languages, Literature and History of Turkish or Turkic*, *5*(3), 919-940.

Creswell, J. W. (2014). *Research design qualitative, quantitative, and mixed methods.* Fourth Edition, SAGE Publications, California.

Draaisma, D. (2007). *Metaphors of memory: A history of ideas about the mind.* Cambridge University Press.

Driver R., & Bell B. (1986). Student's thinking and the learning of science: A constructivist view. School Science Review, March.

Eaglestone, R. (2009). *Metaphors and figures of speech*. Taylor & Francis.

Eilam, B. (2009). The secrets of successful veteran biology teachers: metaphors of evolution, regeneration, and adaptation. *Journal of Teachers and Teaching: Theory and Practice*, *15*(4), 493–513.

Ekici, G. (2016). Determination of the preservice biology teachers' perceptions of microscope: Example for metaphor analysis. *Journal of Kırşehir Education Faculty, 17*(1), 615-636.

Emli, Z., & Afacan, Ö. (2017). The mental models of secondary school 7^{th} class students about global warming. *HAYEF: Journal of Education*, *14-1* (27), 183-202.

Forceville, C. (2002). The identification of target and source in pictorial metaphors. *Journal of Pragmatics, 34*, 1-14.

Gilbert, J. K. (2006). Context based chemistry education on the nature of "context" in chemical education. *International Journal of Science Education*, *28*(9), 957–976.

Goldstein, L. S. (2005). Becoming a teacher as a hero's Journey: Using metaphor in preservice teacher education. *Teacher Education Quarterly*, *32*(1), 7-24.

Guerrero, M., & Villamil, O.S. (2002). Metaphorical conceptualizations of ESL teaching and learning. *Language Teaching Research*, *6*(2), 95-120.

Gürbüzoğlu-Yalmancı, S., & Aydın, S. (2013). Pre-service teachers' metaphorical perceptions towards biology. *Mustafa Kemal University Journal of Graduate School of Social Sciences*, *10*(21), 208-223.

Harman, G., & Çökelez, A. (2017). Pre-service early childhood education teachers' metaphorical perceptions towards chemistry, physics and biology. *Marmara University Atatürk Education Faculty Journal of Educational Sciences*, *46*, 75-95.

Harrison, A. G., & Treagust, D. F. (2006). Teaching and learning with analogies: Friend or foe? In P. J. Aubusson, A. G. Harrison, & S. M. Ritchie, (Eds.), *Metaphor and analogy in science education* (pp.11- 24). Springer.

Hellsten, L., & Nerlich, B. (2011). Synthetic biology: Building the language for a new science brick by metaphorical brick. *New Genetics &Society, 30*(4), 375-397.

https://doi.org/10.33225/jbse/21.20.471

Heywood, J., Elena, S., & Mick, S. (2002). Linguistic metaphor identification in two extracts from novels. *Language and Literature*, *11*(35), 34-54.
Jeppsson, F., Haglund, J., Amin, T. G., & Strömdahl, H. (2013). Exploring the use of conceptual metaphors in solving problems on entropy. *Journal of the Learning Sciences*, *22*(1), 70-120.
Kahyaoğlu, M. (2015). An investigation of the concept of nature among elementary school students through metaphors analysis. *Turkish Studies - International Periodical for the Languages, Literature and History of Turkish or Turkic-*, Journal of Turkish Studies, *10*(11), 821-831.
Konopka, A. K. (2002). Grand metaphors of biology in the genome era. *Computers & Chemistry, 26*(5), 397-401.
Kövecses, Z. (2002). *Metaphor a practical introduction.* Oxford University.
Lakoff, G., & Johnson, M. (2005). *Metaphors we live by*. The University of Chicago Press.
Levine, P. M. (2005). Metaphors and images of classrooms. *Kappa Delta Pi Record*, *41*(4), 172-175.
Lewis, J., & Wood –Robinson, C. (2000). Genes, chromosomes, cell division and inheritance- do students see any relationship? *International Journal of Science Education*, *22*(2), 177-195.
Lopez, J. J. (2007). Notes on metaphors, notes as metaphors: The genome as musical spectacle. *Science Communication*, *29*(7), 1-29.
Mahaffy, P. (2006). Moving chemistry education into 3d: A tetrahedral metaphor for understanding chemistry. *Journal of Chemical Education*, *83*(1), 49-55.
Marton, F. (1981). Phenomenography -Describing conceptions of the world around us. *Instructional Science*, 10(2), 177-200.
Marton, F. (1986). Phenomenography: A research approach to investigating different understandings of reality. *Journal of Thought*, 21(3), 28 - 49.
Martinez, M. A., Sauleda, N., & Huber, G. L. (2001). Metaphors as blueprints of thinking about teaching and learning. *Teaching and Teacher Education*, *17*, 965-977.
Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis*: *An expanded sourcebook.* Sage.
Morgan, G. (1997). *Images of organization*. Sage Publications.
Moser, K. S. (2000). Metaphor analysis in psychology - method, theory, and fields of application. *Qualitative Social Research [On-line journal], 1*(2), 1-10
Neuman, Y. (2005). Meaning making in language and biology. *Perspectives in Biology & Medicine, 48*(3), 317-27.
Oxford, R. L., Tomlinson, S., Barcelos, A., Harrington, C., Lavine, R. Z., Saleh, A. & Longhini, A. (1998). Clashing metaphors about classroom teachers: Toward a systematic typology for the language teaching field. *System, 26*, 3-50.
Özbuğutu, E. (2018). Pre-service science teacher's metaphorical perceptions towards evolution. *Academia Journal of Educational Research*, *3*(1), 28-43.
Pelaez, N. J., Boyd, D. D., Rojas, J. B., & Hoover, M. A. (2005). Prevalence of blood circulation misconceptions among prospective elementary teachers. *Advances in Physiology Education*, *29*, 172-181.
Patton, M. Q. (2014). *Qualitative research and evaluation methods.* Fourth Edition. SAGE publishing
Pishghadam, R., & Pourali, S. (2011). Metaphorical analysis of Iranian Ma students' beliefs: A qualitative study. *Higher Education Studies*, *1*(1), 27-37.
Saban, A. (2009). Prospective teachers' mental images about the concept of student. *The Journal of Turkish Educational Sciences*, *7*(2), 281-326.
Sanchez, A., Jose M. B., & Victor M. (2000). Design of virtual reality systems for education: A cognitive approach. *Education and Information Technologies*, *5*(4), 345-362.
Selvi, M. (2007). Pre-service teachers' perceptions of environmental concepts. Doctoral Thesis, Gazi University, Ankara.
Semerci, Ç. (2007). A view to the new primary school curricula with the metaphors relating to "curriculum development". *Cumhuriyet University Journal of Social Sciences*, *31*(2), 125-140.
Shepardson, D. P., Choi, S., Niyogi, D., & Charusombat, U. (2011). Seventh grade students' mental methods of the greenhouse effect. *Environmental Education Research*, *7*(1), 1-17.
Shuell, T. J. (1990). Teaching and learning as problem solving. *Theory into Practice*, *29*(2), 102–108.
Simon, E. (2015). *Biology: The core.* Pearson Education (p.80-116). Nobel Academic Publishing
Steger, T. (2007). The stories metaphors tell: Metaphors as a tool to decipher tacit aspects in narratives. *Field Methods*, *19*(3), 1-22.
TDK, (2020). Turkish Language Association, https://sozluk.gov.tr/?kelime=biyoloji 27.02.2020.
Tsui, C-Y., &Treagust, D. F. (2007). Understanding genetics: Analysis of secondary students' conceptual status. *Journal of Research in Science Teaching*, *44*(2), 205-235.
Tynavcevic, A., & Vaupot, S. R. (2009). Exploring aspiring principals' perceptions of principalship: A Slovenian case. *Educational Management Administration and Leadership*, *37*(1), 85-105.
Ulukök, Ş., Bayram, K., & Selvi, M. (2015). Pre-service science teachers' mental images towards biology concept [metaphor analysis sample]. *International Online Journal of Educational Sciences*, *7*(3), 244-259.
Venville, G. J., Gribble, S. J., & Donovan, J. (2006). *Metaphors for genes.* In P. J. Aubusson, A. G. Harrison, & S. M. Ritchie (Eds.), *Metaphor and analogy in science education* (pp. 79-91). Springer.
Yapıcı, İ. (2015). High school students' metaphorical perceptions towards biology. *Electronic Journal of Social Sciences*, *14*(55), 139-147.
Yıldırım, A., & Şimşek, H. (2008). *Qualitative research methods in social sciences*. Seçkin Publishing.
Yıldırım, A., & Şimşek, H. (2011). *Qualitative research methods in social sciences*. (8th ed.). Seçkin Publishing.

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ISSN 2538–7138 /Online/

Yob, I. M. (2003). Thinking constructively with metaphors, *Studies in Philosophy and Education*, *22*, 127-138.
Weade, R., & Ernst, G. (1990). Pictures of life in classrooms, and the search for metaphors to frame them. *Theory into Practice, 29*(2), 133–140.
Zvi-Assaraf, O., Dodick, J., & Tripto, J. (2013). High school students' understanding of the human body system. *Research in Science Education, 43,* 1-24.

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EDUCATIONAL EFFICIENCY AND STUDENTS' INVOLVEMENT OF TEACHING APPROACH BASED ON GAME-BASED STUDENT RESPONSE SYSTEM

Branka Radulović

Abstract. *Modern approaches in Physics classes which involve the game-based student response system (GSRS) have been in use for a while, but their educational efficiency and students' involvement have not been examined. Therefore, this research's main aim was to determine the educational efficiency and students' involvement of GSRS and to assess their effect on scientific reasoning. The values of educational efficiency and students' involvement were calculated based on students' achievement and perceived mental effort. To determine these values, a pedagogical experiment with parallel groups was applied. The research was conducted on a sample of 172 secondary school students, and included material related to direct currents. The results point to positive and higher values of the educational efficiency and students' involvement for GSRS approach than the conventional approach. It means that GSRS approach causes lower mental effort, letting more space generate in the working memory to perceive and process new information. The results also show a positive effect of GSRS on higher students' engagement during the class and scientific reasoning. The obtained results undoubtedly indicate the positive effect of GSRS on the students' performance. Therefore, GSRS approach should be used often in the classroom.*

Keywords: *educational efficiency, students' involvement, GSRS, scientific reasoning, teaching physics*

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Introduction

From the moment it was created, game-based student response systems (GSRS) have attracted the attention of numerous researchers intending to determine their effect on students' performance. The primary purpose of using these tools lies in the fundamental problem observed in contemporary education: the lack of student motivation to learn and the lack of engagement during classes (Archer et al., 2020; Clark et al., 2017; Göksün & Gürsoy, 2019). GSRS provides a foundation for making the classrooms fully interactive, enabling students to interact with the teacher and learn subjects in new ways without tremendous cost and effort to administrate and maintain special devices (Wang, 2015). The teacher asks a question, which can be in the form of text, images, or videos through the projector, and students using their mobile phones or appropriate responders give a response to it (Balta et al., 2018; de Freitas, 2006; Licorish et al., 2018; McCaffrey et al., 2014). As soon as they answer, the students immediately receive feedback whether their answer is correct. Also, using the information based on students' responses, the teacher gets the information about the material taught in class, whether it is understandable to students and if there are some misconceptions. In that way, the teacher can have an insight into the transformation of students' state from naive to normative by using the scheme of concept formation (Demkanin & Kováč, 2018; Demkanin, 2018).

Some of the GSRSs are Kahoot and Socrative. According to Vick, as of 2019, over 2.5 billion people from more than 200 countries have played Kahoot, and there are 70 million monthly active unique users (Vick, 2019, according to Wang & Tahir, 2020). Because of such a large number of users, it is crucial to determine educational efficiency (E) and students' involvement (I) of GSRS. E and I's values provide information of occupancy of working memory taking into account the effectiveness of the applied teaching approach and the motivational effect that students experience in learning. Therefore, E and I's values give information on the full effect of a particular teaching approach on students' performance. For the E and I's determination, it is necessary to define standard values of students' achievement (P) and standard values of perceived mental effort as a measurable part of the cognitive load (R). The

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formula for E is: $E = \frac{P - R}{\sqrt{2}}$ (van Gog & Paas, 2008), while for I, the formula is: $I = \frac{R + P}{\sqrt{2}}$ (Paas et al., 2005). In Appendix 1 a graphical representation of these two variables is given.

Measuring the level of students' scientific reasoning is also useful in assessing GSRS approach. Scientific reasoning represents the ability to systematically explore a problem, formulate and test hypotheses, control and manipulate variables, and evaluate experimental outcomes (Han, 2013). These abilities are also necessary for practical work in the Physics laboratory and theoretical tasks (Erlina et al., 2018; Etkina et al., 2010). The scientific reasoning level can be determined by using Lawson's CTSR test (Lawson, 1978, 2004, 2005, 2010). This test includes (1) conservation of matter and volume, (2) proportional reasoning, (3) control of variables, (4) probability reasoning, (5) correlation reasoning, and (6) hypothetical-deductive reasoning (Radulović & Stojanović, 2017). The test gives a much better insight into students' knowledge as it clearly shows whether some of the content is merely memorized or adequately embedded in the student's cognitive structure (Ates & Cataloglu, 2007; Lawson & Thompson, 1988).

Research Problem

Numerous research studies have raised the problem of student motivation for learning, and in this regard, Physics as a subject and students' engagement in Physics classes have been particularly emphasized. The problem of student motivation for learning Physics seems to be worldwide, as it has been recognized in developed countries like UK, India, Japan, the USA, countries in the European Union, and also in non-developed ones (Djudin, 2018). The problem has been observed in decreasing numbers of students interested in studying Physics at university. In response to the problem of student motivation and their engagement during class, a large number of teaching approaches have been developed in recent decades. For some of them, complete information on their effect on student performance, such as educational efficiency, student involvement, and the effects on scientific reasoning, have not been established. Therefore, to ensure student science literacy and the ability to explain scientific phenomena and draw evidence-based conclusions (OECD, 2009, as cited in Demkanin, 2013), it is necessary to obtain complete information on the effects of teaching approaches on student performance. This paper focuses on educational efficiency and student involvement in GSRS approach and its effect on scientific reasoning. The obtained data was compared with the conventional approach to teaching Physics.

Research Focus

With regard to the research problem, the focus will be on the effects of GSRS approach, specifically on determining educational efficiency and student involvement and the effect on student scientific reasoning. Despite significant contributions of other researchers, these values, to the best of the author's knowledge, have not been fully examined. Therefore, the main aim was to determine the educational efficiency and students' involvement of GSRS in Physics classes, and to assess their effect on the level of scientific reasoning. This aim was operationalized through the following research questions:

- Does the GSRS approach reduce the students' mental effort?
- Does the GSRS approach increase the students' understanding of the content related to the electrical current, as measured by DIREC test?
- Which applied teaching approach results in higher value of educational efficiency and students' involvement?
- Does the GSRS approach increase students' scientific reasoning?

Research Methodology

General Background

The fundamental research question is related to determining educational efficiency and student involvement for GSRS approach and its effect on scientific reasoning. This approach uses game elements such as scores, badges, rankings, and rewards in gamification. As such, it leads to student engagement in the learning environment and enforces their behavior to reach targets (Glover, 2013, according to Göksün & Gürsoy, 2019). GSRS combines text,

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audio, and video material which can differently affect student performance, from negative (Mendelson, 2004), slightly positive (Wang & Tahir, 2020), to positive effect (All et al., 2017; Lynch & Keenan, 2018; Tsai & Hsu, 2020). Also, there is a large number of GSRS users in the world. Bearing this in mind, it appears crucial to determine the effect of this approach on students' performance.

To determine educational efficiency and students' involvement and to assess GSRS effect on the level of scientific reasoning, a pedagogical experiment with parallel groups was applied. The research was conducted in the period from March to May 2018, on a convenience sample of 172 students. The preparation of GSRS group students lasted one year in order to obtain the most reliable data on the effects of GSRS approach. The purpose of introducing students to GSRS was to direct their attention on the teaching content rather than the functions of these tools and to find the appropriate number and type of questions. The teaching topic Electric Current was chosen for this research, due to its complexity and abstractness.

Procedure

In this research, a pedagogical experiment with parallel groups, experimental (GSRS) and control (C), was applied. The groups were formed based on already created classes in one secondary school. The principal, the school administration, the students, and their parents were all briefed on the research's conduct. The students who did not agree to participate in the research participated equally in all activities, but their tests were not evaluated and not taken into statistical data processing.

During the first grade of secondary school, the GSRS group of students started working with electronic educational games in their Physics classes. In this way, GSRS was introduced to the students. They mostly used Kahoot and Socrative. The preparation had two aims: to introduce students to GSRS functions, after which they would be more focused on the teaching content, and to find the appropriate number and type of questions. According to All et al. (2017), poor slide-based lectures can cause students lower satisfaction with the learning experience. Therefore, the preparation of questions and other materials should be given a special attention.

For this research, the topic of DC was chosen, as it is one of the most crucial parts of Physics and, at the same time, the most difficult for students. This topic includes high abstraction concepts that are not familiar to students, such as short circuits. According to the curriculum prescribed by the Ministry of Education in the Republic of Serbia, primary school students (13-14 years) learn basic concepts of electric field and electric current. Therefore, before the pedagogical experiment started, a pre-test was performed to determine the initial state.

The pedagogical experiment lasted for 26 hours or 13 weeks. Out of the total number of hours, 22 were for the chosen content, and 4 were devoted to testing. During 22 hours, the GSRS group repeated the material for 10-15 minutes using Kahoot and Socrative. The teacher had previously carefully selected the questions. The same questions were presented to students in the C group but in a conventional way, through an oral examination. In this way, the teacher asked the whole class and only one student could answer, leaving the others without an opportunity to answer the same question. The same teacher taught all the teaching units in both groups to reduce the teacher's influence (such as his/her communication abilities, for example). For this reason, only one secondary school was chosen for the experiment. The experiment was conducted from March to May 2018.

Sample

The sample consisted of 172 students of the second grade of the general-type secondary school in Novi Sad, Republic of Serbia. According to ISCED classification this level corresponds to upper-secondary school. In Serbia there are four types of secondary school (Natural Science and Mathematics, Socio-Linguistic, General, and Specialized). Based on empirical data, the lowest interest in Physics is observed among students of a general-type secondary school. This was the reason why these students participated in the research. The problem of student engagement and interest in Physics has been expressed in decreasing numbers of students interested in studying Physics at university. As this problem is recognized as global, it is crucial to obtain complete information about the teaching approaches. The entire population of all second-grade students of secondary school, all types, from Vojvodina region, was around 3,500 students. For the value of margin of error between 5% and 10%, the research sample of 172 students represented a convenient sample. Both experimental and control groups consisted of 86 students. The age of the second-grade students was from 16 to 17.

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Instrument

In this research, standardized tests were applied. Determining and Interpreting Resistive Electric Circuit Concepts Test (DIRECT) developed by Paula Engelhardt and Robert Beichner was used to assess the degree of knowledge and understanding of terms in the field of Electricity. The pre- and post-tests were the same. DIREC test had 29 items with multiple choices. Data were coded with 1 if the answer was correct and with 0 if it was not. Validation of this test has been confirmed in several papers. The test is available at https://www.physport.org/assessments/assessment.cfm?I=24&A=DIRECT. Cronbach Alpha was 0.861.

The 5-point Likert-type scale followed each item on the knowledge test with descriptors ranging from very easy (code 1) to very difficult (code 5). The students were asked to evaluate how much mental effort they invested. This subjective self-assessment of mental effort has been widely accepted as a reliable method (de Jong, 2010; Milenković et al., 2014; Paas et al., 2003). Cronbach Alpha for the assessment of mental effort was 0.962.

Lawson Classroom Test of Scientific Reasoning (CTSR), developed by Anton Lawson, was applied to determine the level of scientific reasoning. The test was used after the pedagogical experiment. It had 13 questions and 11 sub-questions. Data were coded with 1 if the student answered correctly and gave the correct explanation and 0 if (s)he gave incorrect answers or explanations. The maximum score on this test was 13. The validation of this test has also been confirmed in numerous papers, and the test is available at https://www.physport.org/assessments/assessment.cfm?I=61&A=CTSR. Cronbach Alpha was 0.958. Since the values of Cronbach Alpha for knowledge test, mental effort and scientific reasoning were higher than 0.7, the tests proved as reliable.

Data Analysis

Descriptive statistics, ANOVA, t-test, chi-square, and the neural network model were used to determine the difference in students' knowledge and perceived mental effort. The neural network model was used to determine the contribution of predictors to the explanation of the student achievement variable. The neural networks model determines each predictor's importance without the possibility of multicollinearity between the predictors. This model is based on the training and testing samples. Eta-square indicator was used as an estimator of the size of the variables' effect. Educational efficiency and students' involvement were calculated using appropriate formulas. SPSS.20 program was used for statistical data processing.

Research Results

Students' Achievement on DIREC Test

ANOVA showed that there was no statistically significant difference among students on pre-test, F (df = 1) = 1.26, $p > .05$. Students' achievement in GSRS group was M = 6.28, SD = 1.96, while in C group the values were M = 5.97, SD = 1.70. After equalization of the groups, a pedagogical experiment with parallel groups was applied. The main characteristic of this experiment is that the same teaching contents are processed using different approaches, while the measuring instruments are identical. After the experiment was completed, a post-test (DIRECT) was applied to determine the effect of the applied teaching approach on students' achievement. ANOVA showed that there was a statistically significant difference in students' achievement depending on the applied approach, F (df = 1) = 55.235, $p < .001$, $\eta^2 = 0.25$. In the GSRS group, the mean achievement was M = 13.21, SD = 6.70, while for the C group students, it was M = 7.29, SD = 3.11. To better understand the effect of applied approaches, t-test of paired samples was applied (Table 1).

Table 1
Difference between Pre- and Post-test Within Groups

	M(SD)	t	η^2	df
Cpost - Cpre	1.33 (3.29)	3.739**	0.141	85
$GSRS_{post}$ - $GSRS_{pre}$	6.93 (6.38)	10.080**	0.544	85

* $p < .05$, ** $p < .01$

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As it can be seen, the highest difference between students' achievement on pre- and post-test was obtained in the GSRS group. Eta-square coefficient indicated a large effect size of GSRS on students' achievement. It can be assumed that GSRS approach caused higher students' engagement and their active involvement in the teaching process resulted in higher achievement. The more agile students of the GSRS group were encouraged to develop a competitive spirit, and those introverted were given a chance to express their cognitive potentials. In this way, more students are actively involved in the teaching process, which is especially important for classes with a larger number of students. In this particular case, classes with 30 students were included in the research. With the conventional approach a small number of students could answer the teacher's questions, while GSRS offered that possibility to everyone. Knowing that they will not have the opportunity to express their cognitive potentials, introverted persons in the conventional approach remain unrecognizable, i.e., unnoticed by the teacher. In such a situation, the teacher cannot correct his/her approach and may not respond to students' cognitive demands or eliminate certain misconceptions.

Looking at DIRECT items, the GSRS group students gave significantly better answers to all of the items than their C group peers. A problem that resulted in a more considerable difference between the groups referred to calculating the power of a resistor. The students got a starting situation; a simple circuit made up of a power source and one resistor. Then another resistor was placed in the circuit. The students were to decide if the electric current's power brought into the resistor changed; whether it increased/decreased or there were no changes. The proportion of correct answers of students in the GSRS group was 57%, while in the C group it was 1%. There were also some other examples with an electric circuit, including parallel-connected light bulbs or where a light bulb replaced the resistor.

The most challenging question for both groups of students was the question related to the creation of the electric field. The students had to answer whether the electric field inside the bulb fiber equaled zero or was different from zero. The percentage of correct answers to this question was 24% and 9%, for the GSRS and C group, respectively.

To assess GSRS approach in relation to student performance, it is necessary to determine its effect on students' cognitive load and mental effort as a measurable part. The mental effort information points to the cognitive capacity allocated to the task and the working memory occupancy. Depending on its size, the process of learning can be interrupted.

Perceived Mental Effort

ANOVA showed that there was no difference between the groups in perceived mental effort on pre-test, F ($df = 1$) = 3.136, $p > .05$. Mental effort in C group was $M = 2.59$, $SD = 0.85$, while for GSRS group it was $M = 2.83$, $SD = 0.95$. After the pedagogical experiment ANOVA pointed to a difference between the groups, F ($df = 1$) = 5.537, $p < .05$, $\eta^2 = 0.03$. The students in the C group reported slightly less mental effort $M = 2.09$, $SD = 0.82$, while in the GSRS group a considerably lower mental effort was reported in comparison with the values before the experiment $M = 1.80$, $SD = 0.77$. Table 2 presents t-test of paired samples.

Table 2
Difference in Perceived Mental Effort on Pre- and Post-test

	M(*SD*)	*t*	η^2	*df*
C_{post} - C_{pre}	0.50 (1.05)	4.418**	0.187	85
$GSRS_{post}$ - $GSRS_{pre}$	1.03 (1.10)	8.688**	0.470	85

* $p < .05$, ** $p < .01$

A decrease of perceived mental effort was obtained in both groups, but there was a difference in the size effect. Eta-square showed a moderate effect of GSRS approach on the decrease of perceived mental effort. Viewed by categories (Figure 1), in the GSRS group, a significant reduction in category (difficult) was detected by about 25%, and a significant increase of the lowest perceived effort (very easy) by about 30%. There were also changes in the C group's perceived mental effort, but these changes were less intense than in the GSRS group.

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Figure 1
Difference in Perceived Mental Effort on Pre- and Post-test

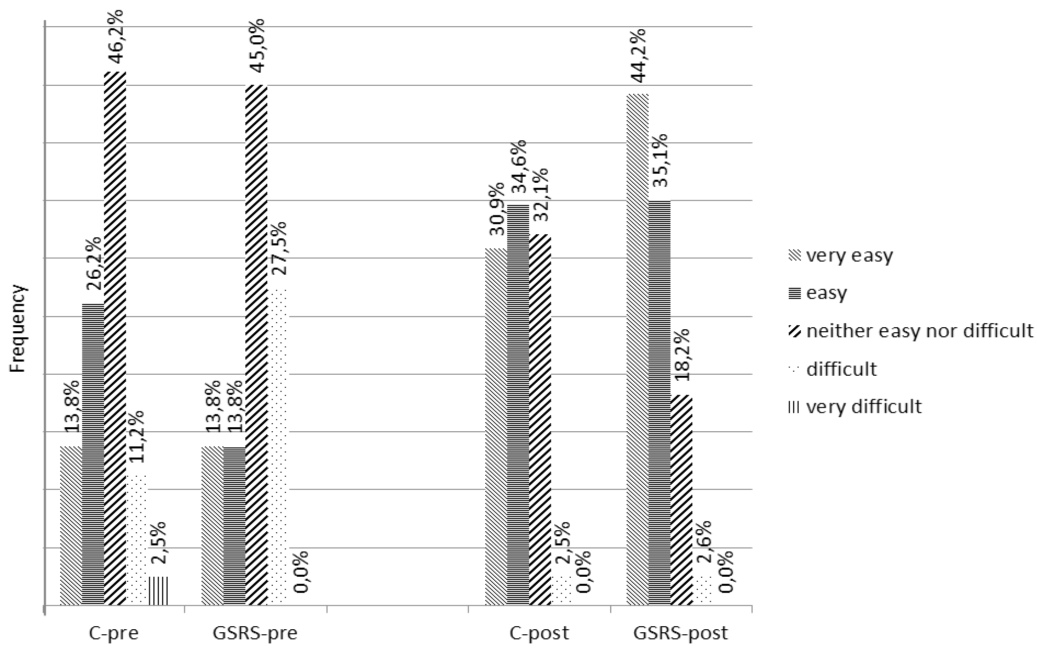
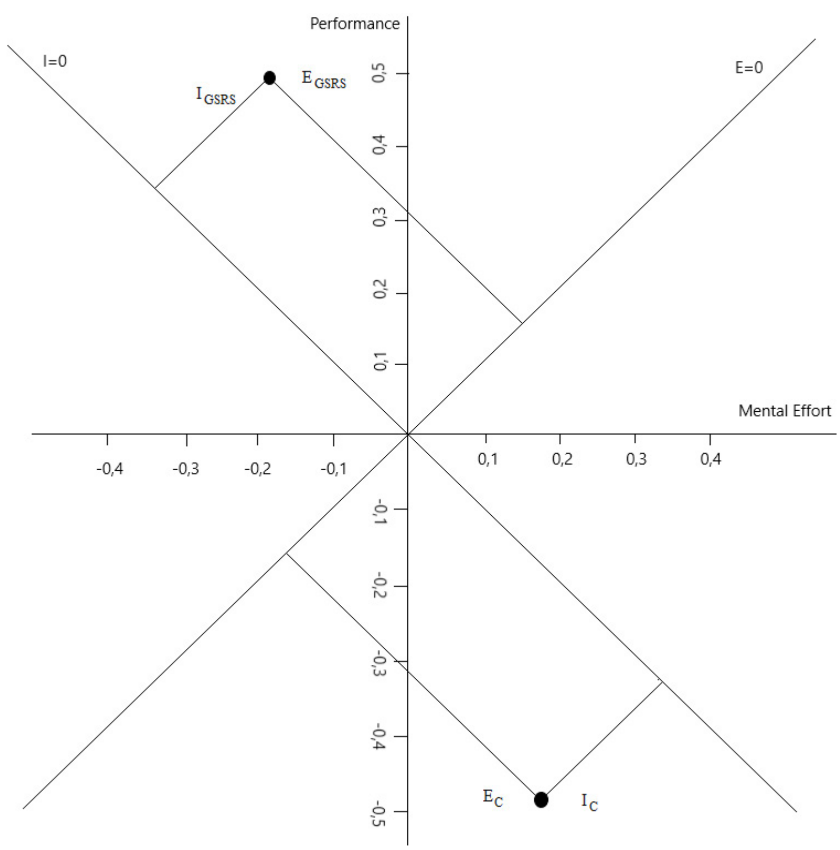


Figure 2 shown the educational efficiency (E) and students' involvement (I).

Figure 2
Educational Efficiency and Students' Involvement



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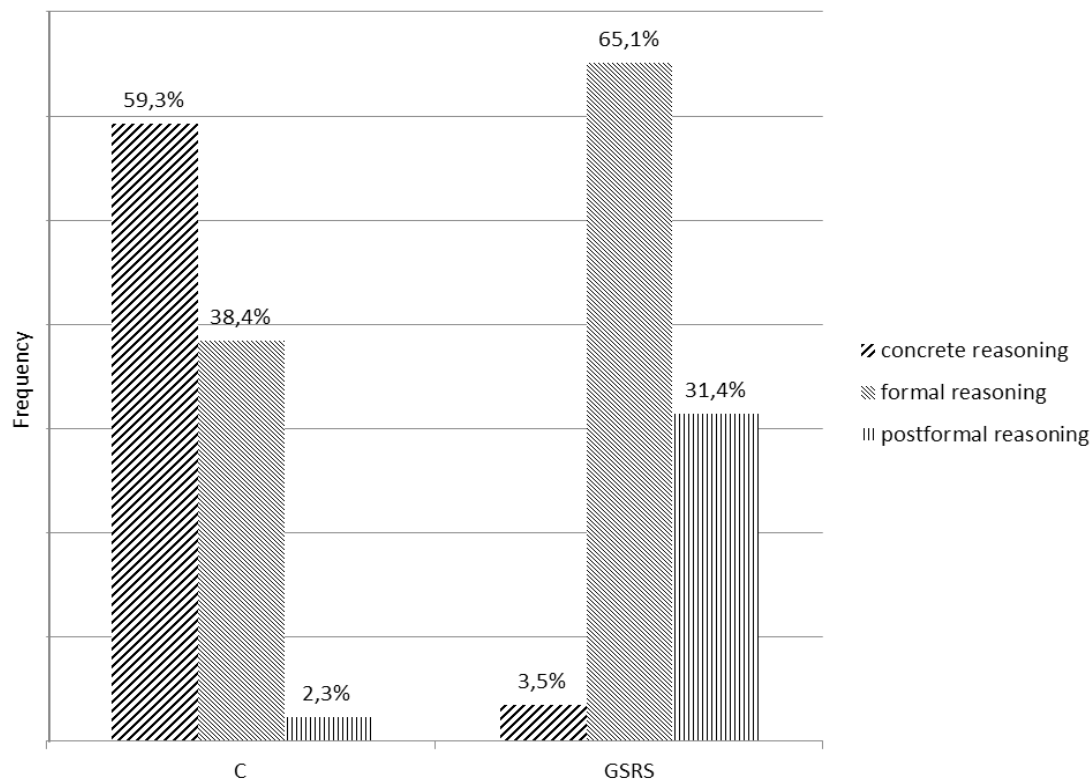
Applying the formulas by Paas and coworkers, the obtained value of educational efficiency for the GSRS group was $E_{GSRS} = 0.504$, while for the C group was $E_C = -0.705$. As for students' involvement, the values were $I_{GSRS} = 0.226$ and $I_C = -0.221$. According to the obtained values, GSRS appeared much more effective for students than the conventional approach. GSRS caused less mental effort, leaving more space in working memory to perceive and process new information.

Level of Scientific Reasoning

During the final testing, the students' scientific reasoning level was assessed. The chi-square test showed a statistically significant difference in the level of scientific reasoning depending on the applied teaching approach, $\chi^2(df = 2) = 70.162$, $p < .001$, Cramers $V = 0.639$ (Figure 3).

Figure 3
Effect of Teaching Approaches on the Level of Scientific Reasoning



More students in the GSRS group were at the highest post-formal level than in the C group. At this level, abstract thinking develops. It means that students become able to reason in abstract categories and make conclusions by using deduction. On the other hand, the students of group C at a concrete level use inductive reasoning. They can memorize teaching content, but not generalize physical laws and principles. In other words, it means that the C group students were unable to do items related to conducting experiments. These students were unable to notice the existence of dependence between the presented variables.

Model of Neural Networks

A model of neural networks was used to determine the predictor's contribution: applied teaching approach, perceived mental effort, and the level of scientific reasoning on the variance in student achievement. The training

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sample for the applied model's validity was 93.5%, while the test sample was 80.0%. The AUROC (area under the ROC curve) that gives the model's accuracy was 0.923. Table 3 shows both the importance and the normalized importance of each predictor in determining the neural network.

Table 3
Importance and Normalized Importance of Each Predictor

	Importance	Normalized importance (%)
Teaching approach	0.439	100.0
Scientific reasoning	0.315	71.8
Mental effort	0.246	56.0

The obtained data indicate that all predictors were significant, with normalized importance of more than 50%. Accordingly, to increase students' achievement, it is necessary to apply such a teaching approach that will cause an increase in the level of scientific reasoning and, at the same time, decrease the perceived mental effort.

Discussion

The interest in using digital games as educational tools has increased enormously over the past decade (All et al., 2017; Lynch & Keenan, 2018), which demands better teachers' knowledge and skills in using the modern technology (Demkanin, 2020; Demkanin & Novotná, 2021). This approach combines the entertaining power of digital games and teaching content. The positive effect of the approach on students' engagement and achievement has been observed, but still, to the best of the author's knowledge, its educational efficiency and students' involvement have not been fully assessed.

The obtained results have pointed to a considerably positive effect of GSRS approach on students' achievement. The GSRS group students achieved higher values on the knowledge test than their C group peers. This suggests that students better understand the teaching content and appear more focused on it when they use GSRS. Differences were particularly noticed for the group of items related to the brightness of parallel bulbs in some current or with the bulb's resistance after the switch is open. More students in the GSRS group gave correct answers to almost every item than it was the case with the C group students.

Dervan (2014) found that using Socrative, one of the used GSRS in this research, lectures became more interactive and highlighted students' gaps in knowledge. Also, Socrative improved students' engagement during lectures and helped the teacher understand where students had a difficulty. According to Caldwell, some students said that they paid more attention and focused more on content because they knew they had to use this knowledge at the end of the lecture to compete in a knowledge competition (Caldwell, 2007, according to Wang, 2015). Those very competitive ones had even read the textbook more carefully before coming to lectures to beat the classmates. Raising students' motivation to learn positively affects their interest in the subject and their achievements (Habgood & Ainsworth, 2011; Olić et al., 2016). Also, higher results on the knowledge tests cause increasing student motivation to learn. Due to the complex correlation between motivation and achievement, the researchers' task is to find ways to increase one variable, which will cause an increase in the other one. However, some studies report the positive effect of electronic games (Supercharged) in teaching Physics, but still students' knowledge of the topic was rated lower than in the control group (Anderson & Barnett, 2011). Kao et al. (2017) found that post hoc comparisons show that the scaffolding group's marking critical features scored significantly higher than both the demonstration and the non-scaffolding groups. Positive effects of game-based learning were also shown in a research by Sengupta et al. (2015). Their study showed the design of conceptually integrated games for learning Newtonian physics. According to Clark et al., well-designed games can scaffold student learning (Clark et al., 2009, according to Sengupta et al., 2015).

According to the present results, GSRS approach had a considerably positive effect on decreasing the students' perceived mental effort. After determining the perceived mental effort and achievement, educational efficiency and students' involvement were calculated. The results undoubtedly indicate that the values for educational efficiency and students' involvement for GSRS approach are positive. The results point out and

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confirm the positive effect of GSRS approach on students' performance. The students were more engaged and focused on the content, and the classroom atmosphere was more dynamic compared to the conventional approach classes.

The obtained results point to the positive effect of GSRS approach on increasing scientific reasoning. More students in the GSRS group achieved a higher level of scientific reasoning than in the C group. It means that students can consistently test the hypotheses using observed or unobserved agents or entities (Lawson et al., 2007). Therefore, the starting point is not in the observed agents or entities, but in theoretical (hypothetical) relations that establish or verify real relations between phenomena (Stepanović, 2004a, 2004b). Postformal reasoning level is essential for understanding physics concepts and phenomena. Therefore, researchers are searching for different teaching approaches which will positively affect scientific reasoning and have positive values of E and I. Some of these approaches are based on using modern technology. Technology can play a significant role in helping learners use higher-order thinking skills to plan and conduct research, manage projects, and solve problems through appropriate digital tools and resources (ISTE, 2007, according to Lee & Choi, 2017). However, it is vital to use digital tools properly because they are just tools, not a goal by themselves. According to Lee and Choi (2017), when technology-enhanced learning for higher-order thinking is well-designed, it may not produce desired outcomes, as this also depends on learner factors. In this particular case, the familiarization of the GSRS students with GSRS work lasted the whole year to find an acceptable way of presenting questions and introducing students to GSRS.

Psycharis (2013) confirmed the positive effect of computational models on students' performance. Moreover, students' active role in their classrooms positively affects scientific reasoning (Erlina et al., 2018). The potentials of digital games can be used to promote collaborative problem-solving, to provide effective learning environments, and to facilitate science learning for younger students (Li & Tsai, 2013). To enhance learning and teaching, game designers should embed meta-cognitive activities, such as reflective opportunities into educational video games to provide scaffolds for students and reinforce that they are engaged in an educational learning experience (Anderson & Barnett, 2013).

Conclusions and Implications

Although GSRS approach has been in use in Physics lessons for a while, there is limited empirical evidence on its effect on student performance. The present study contributes to this lack of evidence by assessing the educational efficiency, students' involvement, and the level of students' scientific reasoning of GSRS in relation to the conventional approach in Physics classes. It has been found that GSRS results in better students' performance on DIREC test and causes less mental effort in solving tasks than the conventional approach. The obtained values for the estimated educational efficiency, students' involvement, and the level of scientific reasoning have also confirmed that GSRS approach is more appropriate for students than the conventional teaching and learning. On the basis of the overall results, it can be concluded that the present study offers a sound empirical evidence on the positive effects of the implementation of GSRS approach. Physics teachers are now given a better insight into GSRS application and the findings are intended to encourage more and more teachers to apply GSRS in their classrooms. Further research, however, should compare GSRS approach with other student-centered approaches to find the most suitable way of teaching and learning. It would also be necessary to apply a retention test in future studies.

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References

All, A., Plovie, B., Castellar, E. P. N., & Van Looy, J. (2017). Pre-test influences on the effectiveness of digital-game based learning: A case study of a fire safety game. *Computers & Education*, *114*, 24-37. http://dx.doi.org/10.1016/j.compedu.2017.05.018

Anderson, J., & Barnett, M. (2011). Using video games to support pre-service elementary teachers learning of basic physics principles. *Journal of Science Education and Technology*, *20*(4), 347-362. https://doi.org/10.1007/s10956-010-9257-0

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Anderson, J. L., & Barnett, M. (2013). Learning physics with digital game simulations in middle school science. *Journal of Science Education and Technology*, *22*(6), 914-926. https://doi.org/10.1007/s10956-013-9438-8

Archer, L., Moote, J., & MacLeod, E. (2020). Learning that physics is 'Not for Me': Pedagogic work and the cultivation of habitus among advanced level physics students. *Journal of the Learning Sciences*, *29*(3), 347-384. https://doi.org/10.1080/10508406.2019.1707679

Ates, S., & Cataloglu, E. (2007). The effects of students' reasoning abilities on conceptual understandings and problem-solving skills in introductory mechanics. *European Journal of Physics*, *28*(6), 1161-1171. https://doi.org/10.1088/0143-0807/28/6/013

Balta, N., Perera-Rodríguez, V. H., & Hervás-Gómez, C. (2018). Using Socrative as an online homework platform to increase students' exam scores. *Education and Information Technologies*, *23*(2), 837-850. https://doi.org/10.1007/s10639-017-9638-6

Cerniglia, A. J. (2012). *Instructional efficiency and learner involvement*, Doctoral work, http://andrewcerniglia.com/?p=411#comments

Clark, D. B., Tanner-Smith, E., Hostetler, A., Fradkin, A., & Polikov, V. (2017). Substantial integration of typical educational games into extended curricula. *Journal of the Learning Sciences*, *27*(2), 265-318, https://doi.org/10.1080/10508406.2017.1333431

Dakka, S. M. (2015). Using Socrative to enhance in-class student engagement and collaboration. International *Journal on Integrating Technology in Education*, *4*(3), 13-19. https://doi.org/10.5121/ijite.2015.4302

Demkanin, P. (2013). Preparation of new physics teachers from various perspectives. *Journal of Baltic Science Education*, *12*(1), 4-5.

Demkanin, P. (2018). Concept formation: Physics teacher and his know-how and know-why. *Journal of Baltic Science Education*, *17*(1), 4-7. https://doi.org/10.33225/jbse/18.17.04

Demkanin, P., & Kováč, M. (2019, May). Physics experiments planned by the students themselves-Higher Secondary Education. In Fernando J. Garrigós Simón, Sofía Estellés Miguel, Ismael Lengua Lengua, José Onofre Montesa, Carlos M. Dema Pérez, Juan Vicente Oltra Gutiérrez, Yeamduan Narangajavana, María José Verdecho Sáez (eds), *INNODOCT/18. International Conference on Innovation, Documentation and Education* (pp. 23-33). Editorial Universitat Politècnica de València.

Demkanin, P. (2020). The ways the theory of physics education can evolve. *Journal of Baltic Science Education*, *19*(6), 860-863. https://doi.org/10.33225/jbse/20.19.860

Demkanin, P., & Novotná, S. (2021, March). Selected aspects of tutoring and scaffolding pre-service physics teachers. In L. Gómez Chova, A. López Martinez, I. Candel Torres (eds.), *INTED2021 Proceedings* (Vol. 8, p. 8710-8716). IATED.

Dervan, P. (2014). Increasing in-class student engagement using Socrative (an online Student Response System). *AISHE-J: The All Ireland Journal of Teaching and Learning in Higher Education*, *6*(3), 1801-18013.

de Freitas, S. I. (2006). Using games and simulations for supporting learning. *Learning, Media and Technology*, *31*(4), 343-358. https://doi.org/10.1080/17439880601021967

de Jong, T. (2010) Cognitive load theory, educational research, and instructional design: Some food for thought. *Instructional Science*, *38*, 105-134. https://doi.org/10.1007/s11251-009-9110-0

Djudin, T. (2018). How to cultivate students' interests in physics: A challenge for senior high school teachers. *Jurnal Pendidikan Sains*, *6*(1), 16 - 22. http://dx.doi.org/10.17977/jps.v6i1.10543

Erlina, N., Susantini, E., Wasis, W., & Pandiangan, P. (2018). The effectiveness of evidence-based reasoning in inquiry-based physics teaching to increase students' scientific reasoning. *Journal of Baltic Science Education*, *17*(6), 972-985. https://doi.org/10.33225/jbse/18.17.972

Etkina, E., Karelina, A., Ruibal-Villasenor, M., Rosengrant, D., Jordan, R., & Hmelo-Silver, C. E. (2010). Design and reflection help students develop scientific abilities: Learning in introductory physics laboratories. *Journal of the Learning Sciences*, *19*(1), 54-98, https://doi.org/10.1080/10508400903452876

Göksün, D. O., & Gürsoy, G. (2019). Comparing success and engagement in gamified learning experiences via Kahoot and Quizizz. *Computers & Education*, *135*, 15-29. https://doi.org/10.1016/j.compedu.2019.02.015

Habgood, J. M. P., & Ainsworth, S. E. (2011). Motivating children to learn effectively: Exploring the value of intrinsic integration in educational games. *Journal of the Learning Sciences*, *20*(2), 169-206, https://doi.org/10.1080/10508406.2010.508029

Han, J. (2013). *Scientific reasoning: Research, development, and assessment* (Doctoral dissertation, The Ohio State University). The Ohio State University and OhioLINK. https://etd.ohiolink.edu/apexprod/rws_olink/r/1501/10?clear=10&p10_accession_num=osu1366204433

Kao, G. Y. M., Chiang, C. H., & Sun, C. T. (2017). Customizing scaffolds for game-based learning in physics: Impacts on knowledge acquisition and game design creativity. *Computers & Education*, *113*, 294-312. http://dx.doi.org/10.1016/j.compedu.2017.05.022

Lawson, A. E. (1978). The development and validation of a classroom test of formal reasoning. *Journal of Research in Science Teaching*, *15*(1), 11-24.

Lawson, A. E., & Thompson, L. D. (1988). Formal reasoning ability and misconceptions concerning genetics and natural selection. *Journal of Research in Science Teaching*, *25*(9), 733-746.

Lawson, A. E. (2004). The nature and development of scientific reasoning: A synthetic view. *International Journal of Science and Mathematics Education*, *2*(3), 307-338. https://doi.org/10.1007/s10763-004-3224-2

Lawson, A. E. (2005). What is the role of induction and deduction in reasoning and scientific inquiry? *Journal of Research in Science Teaching*, *42*(6), 716-740. https://doi.org/10.1002/tea.20067

Lawson, A. E., Banks, D. L., & Logvin, M. (2007). Self-efficacy, reasoning ability, and achievement in college biology. *Journal of Research in Science Teaching*, *44*(5), 706-724. https://doi.org/10.1002/tea.20172

https://doi.org/10.33225/jbse/21.20.495

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Lawson, A. E. (2010). Basic inferences of scientific reasoning, argumentation, and discovery. *Science Education*, *94*(2), 336-364. https://doi.org/10.1002/sce.20357

Lee, J., & Choi, H. (2017). What affects learner's higher-order thinking in technology-enhanced learning environments? The effects of learner factors. *Computers & Education*, *115*, 143-152. https://doi.org/10.1016/j.compedu.2017.06.015

Li, M. C., & Tsai, C. C. (2013). Game-based learning in science education: A review of relevant research. *Journal of Science Education and Technology*, *22*(6), 877-898. https://doi.org/10.1007/s10956-013-9436-x

Licorish, S. A., Owen, H. E., Daniel, B., & George, J. L. (2018). Students' perception of Kahoot!'s influence on teaching and learning. *Research and Practice in Technology Enhanced Learning*, *13*(1), 9-31. https://doi.org/10.1186/s41039-018-0078-8

Lynch, D., & Keenan, M. (2018). The good behavior game: Maintenance effects. *International Journal of Educational Research*, *87*, 91-99. https://doi.org/10.1016/j.ijer.2016.05.005

Mendelson, A. L. (2004) For whom is a picture worth a thousand words? Effects of the visualizing cognitive style and attention on processing of news photos. *Journal of Visual Literacy*, *24*(1), 1-22. https://doi.org/10.1080/23796529.2004.11674600

McCaffrey, T., Krishnamurty, S., & Lin, X. (2014). Cahoots: A software platform for enhancing innovation and facilitating situation transfer. *Research & Practice in Technology Enhanced Learning*, *9*(1), 145-163.

Milenković, D. D., Segedinac, M. D., & Hrin, T. N. (2014). Increasing high school students' chemistry performance and reducing cognitive load through an instructional strategy based on the interaction of multiple levels of knowledge representation. *Journal of Chemical Education*, *91*(9), 1409-1416. https://doi.org/10.1021/ed400805p

Olić, S., Ninković, S., & Adamov, J. (2016). Adaptation and empirical evaluation of the questionnaire on students' motivation towards science learning. *Psihologija*, *49*(1), 51-66. https://doi.org/10.2298/PSI1601051O

Paas, F., Tuovinen, J. E., Tabbers, H., & Van Gerven, P. W. M. (2003). Cognitive load measurement as a means to advance cognitive load theory. *Educational Psychologist*, *38*(1), 63-71. https://doi.org/10.1207/S15326985EP3801_8

Paas, F., Tuovinen, J. E., Van Merrienboer, J. J., & Darabi, A. A. (2005). A motivational perspective on the relation between mental effort and performance: Optimizing learner involvement in instruction. *Educational Technology Research and Development*, *53*(3), 25-34. https://doi.org/10.1007/BF02504795

Psycharis, S. (2013). Examining the effect of the computational models on learning performance, scientific reasoning, epistemic beliefs, and argumentation: An implication for the STEM agenda. *Computers & Education*, *68*, 253-265. http://dx.doi.org/10.1016/j.compedu.2013.05.015

Radulović, B., & Stojanović, M. (2017). A study of the measurement characteristics of Lawson's test and its relationship to socio-demographic variables and physics grades. *Nastava i Vaspitanje*, *66*(3), 497-514. https://doi.org/10.5937/nasvas1703497R

Sengupta, P., Krinks, K. D., & Clark, D. B. (2015). Learning to deflect: Conceptual change in Physics during digital game play. *Journal of the Learning Sciences*, *24*(4), 638-674. https://doi.org/10.1080/10508406.2015.1082912

Stepanović, I. (2004a). The investigation of formal operational thinking on the age 14-19. *Psihologija*, *37*(2), 163-181. https://doi.org/10.2298/PSI0402163S

Stepanović, I. (2004b). The formal operations: Piaget's concept, researches and main critics. *Psihologija*, *37*(3), 311-334. https://doi.org/10.2298/PSI0403311S

Tsai, F. H., & Hsu, I. (2020). Exploring the effects of guidance in a computer detective game for science education. *Journal of Baltic Science Education*, *19*(4), 647-658. https://doi.org/10.33225/jbse/20.19.647

van Gog, T., & Paas, F. (2008). Instructional efficiency: Revisiting the original construct in educational research. *Educational Psychologist*, *43*(1), 16-26. https://doi.org/10.1080/00461520701756248

Wang, A. I. (2015). The wear out effect of a game-based student response system. *Computers & Education*, *82*, 217-227. http://dx.doi.org/10.1016/j.compedu.2014.11.004

Wang, A. I., & Tahir, R. (2020). The effect of using Kahoot! for learning–A literature review. *Computers & Education*, *149*, 103818. https://doi.org/10.1016/j.compedu.2020.103818

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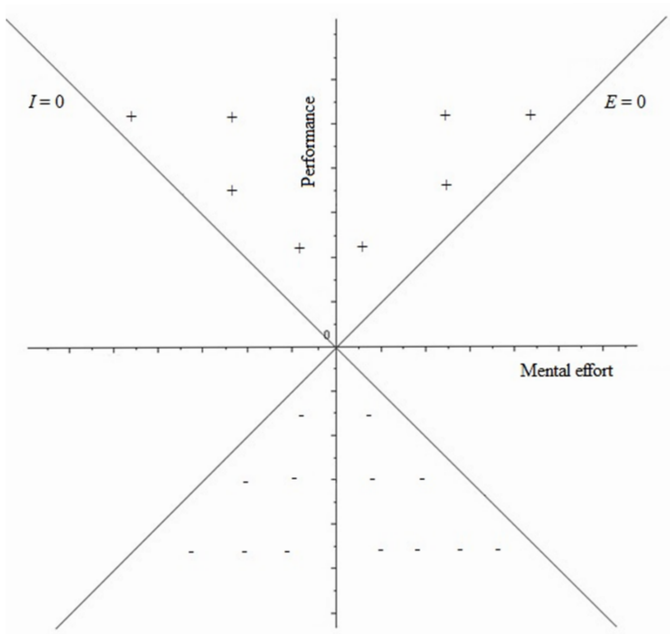
Appendix 1

Figure 4
Graphical presentation of educational efficiency and students' involvement (adapted according to Cerniglia, 2012)



If the point representing one teaching approach is above the curves, then that approach has positive values for E and I, i.e., if the point is below the curves, the applied approach has negative values. Therefore, the teaching approach with positive E, and I cause higher achievement and lower mental effort.

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THE ALIGNMENT BETWEEN THIRD-GRADE PRIMARY SCHOOL SCIENCE TEXTBOOKS AND CURRICULUM STANDARDS IN CHINA AND JAPAN

Lihui Sun,
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Abstract. *This study applied the Porter's alignment model to construct a localized two-dimensional framework based on Anderson's taxonomy. The research chose the third-grade primary school science textbooks from two representative presses in China and Japan, coded the textbooks and curriculum standards, calculated the alignment level between the textbooks of the two presses and their corresponding curriculum standards, and discussed the alignment level from the topic, cognitive demand, and emphasis. The results show that the B version in Japan is significantly aligned with the Japanese curriculum standard, but the A version in China does not have significant alignment with the Chinese curriculum standard. Besides, a common problem is that the ratios of life science in sample science textbooks both exceed the requirements of the curriculum standards, and the problems of exceeding the standard in cognitive demand and not highlighting the key points also need to be concerned. This study provides ideas and references for countries with similar educational situations to study the compilation of science textbooks and fills up the deficiency of the international comparison of the alignment between primary school science textbooks and curriculum standards by using the alignment model.*

Keywords: *alignment evaluation, content analysis, curriculum standards, primary school, science textbooks*

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Introduction

Textbooks play an irreplaceable role in promoting students' mastery of scientific knowledge and organization of learning activities. Besides, textbooks are the factor affecting students' academic performance (Aldahmash et al., 2016; Andersen, 2020; Polikoff, 2015), and the guarantee for teachers to implement curriculum standards (Hill, 2001), so it is necessary to examine the textbooks (Vojíř & Rusek, 2021). Under the standards-based reform, standards become the important basis of measurement, guide the curriculum development and classroom teaching, and put forward clear goals and expectations for teachers to improve teaching quality and students to improve their academic performance (Troia et al., 2018). Improving the alignment among various components of the education system is of great significance for ensuring the quality of education, achieving the expected goals, and carrying out the evaluation work (Fulmer et al., 2018; Newton & Kasten, 2013; Qhibi et al., 2020). Therefore, as the educational components, it is necessary to achieve a high degree of alignment between textbooks and curriculum standards.

Under the background of the new round of curriculum reform, it was pointed out that the curriculum standards are the basis for the compilation of textbooks in China (Ministry of Education, 2001). In 2017, the new version of primary school science curriculum standard was promulgated in China (Ministry of Education, 2017), then the new primary school science textbooks were published by various presses. However, it is not clear whether the new primary school science textbooks really follow the requirements of the curriculum standard and maintain a high alignment level with the curriculum standard. As a neighbour of China, the reform based on curriculum standards also started in Japan and achieved some results (Ministry of Education, Culture, Sports, Science and Technology-Japan (MEXT), 2019). Especially in the field of science education, Japanese students have performed well in international tests such as The Program for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) in recent years (MEXT, 2019; MEXT, 2020). Since China and Japan have certain similarities in

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educational background, such as both countries have nine-year compulsory education and require children to enter primary school at the age of six (MEXT, 2015; The National People's Congress, 2019; Tian, 2015), comparing the alignment of primary school science textbooks and curriculum standards in two countries, may be helpful to obtaining findings that can provide some reference for the development of primary school science textbooks.

Alignment Models

In order to examine the level of alignment among educational components such as standards, assessment and so on, researchers have established different alignment methods with different characteristics. Webb (1999) defined alignment as the degree of alignment between expectation and assessment. The model he established was evaluated from four dimensions, categorical concurrence, depth-of-knowledge consistency, range-of-knowledge correspondence, and balance of representation. Porter's alignment model established the Porter's alignment formula, from two dimensions of the topic and cognitive demand to construct the framework (Porter, 2002; Porter et al. 2007). Porter's model can be applied to international comparison and can be analysed and compared from the overall alignment index and the two dimensions respectively (Liu et al., 2009). Achieve model was used to analyse the alignment between the evaluation project and the standards from the aspects of content centrality and performance centrality, the challenge of the evaluation project, and the balance and range of knowledge (Rothman et al. 2002).

In the existing research on the application of alignment models, most researchers prefer to analyse the alignment between academic assessment and curriculum standard. For example, based on the Webb's model, Webb (1999) analysed the alignment between math and science assessments and standards in basic education in four states of the United States, and found that there were great differences among different states. Fitzpatrick et al. (2015) conducted a study on the alignment between the assessment and curriculum standard of therapeutics courses in Canadian higher education and found that the results were unsatisfactory. Based on the Porter's model, Liang and Yuan (2008) and Liu et al. (2009) both studied the degree of alignment between the standardized test and the curriculum standards of middle school physics in China, and the data both proved the poor alignment level. Similarly, Lu and Liu (2012) tested the alignment between middle school biology standardized tests and curriculum standard in China and found that there was no significant alignment between tests and curriculum standard in four provinces. Contino (2013) analysed the alignment of examinations and curriculum standard of earth science in New York, and the results also showed that the alignment was not ideal.

In addition, there have been less studies about the alignment between teaching materials and curriculum standards. Qhibi et al. (2020) conducted a study on alignment between content standard and practice materials in high school mathematics and concluded that the results were acceptable but needed further adjustment. Polikoff et al. (2015) tested the alignment of primary school mathematics textbooks and curriculum standards and found that the alignment index was not high. It can be found that in the existing studies, there is insufficient research on the alignment of teaching materials with curriculum standards, and the research subjects mostly focus on mathematics.

Alignment Between Science Textbooks and Curriculum Standards

Science education has attracted more and more international attention, and the cultivation of scientific literacy has become an important part of education in various countries (Çakici, 2012). Science textbooks are the indispensable part of science education, so researchers have explored science textbooks from different perspectives (Gilavand et al., 2016; Røthing,2017; Yacoubian et al., 2017).

With the deepening of standards-based reform, some researchers began to pay attention to the relationship between science textbooks and curriculum standards and tried to evaluate whether science textbooks meet the requirements of standards. Although many science textbook publishing houses have claimed that their books were written according to the curriculum standards, some research results indicated that the science textbooks still did not meet the requirements of the curriculum standards. For example, aiming at the content of the nature of science in science textbooks, Abd-El-Khalick et al. (2008) and Li et al. (2020) scored the middle school chemistry textbooks and the middle school physics textbooks respectively, the results show that the textbooks were not well aligned with the current science curriculum standards and science education reform documents. As for the content of the science inquiry in science textbooks, Aldahmash et al. (2016) analysed the science inquiry of several science textbooks in Saudi Arabia and found that textbooks did not contain all the features of inquiry, as they were

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not aligned with the National Science Education Standard. Similarly, Li et al. (2018) pointed out that the inquiry activities in China's five versions of the physics textbooks were also not in line with the requirement of paying attention to the importance of scientific inquiry in science education advocated in the science curriculum standard.

Although some researchers have pointed out that some of the current science textbooks were not aligned with the standards in some respects, it was found that most of the current related studies focus on the middle school science textbooks, but less on the primary school science textbooks. In addition, there is a lack of research on applying the alignment models to analyse the alignment level between science textbooks and the standards on the whole, so the study of the alignment between science textbooks and standards needs to be further strengthened.

Research Aim and Research Questions

The existing research on science textbooks mostly started from a certain part of the content of textbooks, such as the scientific inquiry activities in textbooks, to explore whether its setting is in line with the concept advocated by curriculum standards. However, there is less attention on the setting of curriculum standards, and there is also a lack of comparative research on the alignment between science textbooks and curriculum standards in different countries by using the model. This study not only aims to discuss the compilation of science textbooks from the perspective of curriculum standards by calculating the alignment level between curriculum standards and science textbooks, but also aims to understand the alignment level between science textbooks and curriculum standards in different countries through international comparative research, so as to achieve the purpose of international mutual reference.

In addition, children's intelligence in primary school has experienced a transition from the main form of concrete image thinking to the main form of abstract logic thinking, and the third and fourth grades are just the key period of transition (Lin, 2011). Therefore, this study takes the third-grade primary school science textbooks and curriculum standards in China and Japan as the analytical material, carries out comparative analysis and discussion on the alignment between primary school science textbooks and curriculum standards, and identifies the following research questions:

1. What is the alignment level between the third-grade primary school science textbook of the A version in China and the Chinese science curriculum standard?
2. What is the alignment level between the third-grade primary school science textbook of the B version in Japan and the Japanese science curriculum standard?
3. What references and suggestions can be provided for the compilation of primary school science textbooks through the comparative study between China and Japan?

Research Methodology

General Background

In this study, the Porter's alignment model was selected as the instrument and adjusted in its localization. Based on this framework, content analysis and coding were carried out for the text contents of the Chinese and Japanese third-grade primary school science textbooks and their corresponding curriculum standards. The coding results of the two countries were substituted into the Porter's alignment formula to obtain the alignment level, then the results were compared and discussed.

Selection of Materials for Analysis

In order to examine the alignment level between textbooks and curriculum standards, the curriculum standards and textbooks need to be coded. The new science curriculum standards for primary schools in China and Japan were both released in 2017, and the learning objectives and contents of each grade were clearly defined in the standards. Since the description of the learning objectives was detailed and with high operability, such as "Through the observation, describing the hot air rising phenomenon", so the learning objectives in the curriculum standards became the reference for coding.

For the selection of textbooks, the third-grade primary school science textbook (version A) published by the Chinese publishing house A, and the third-grade primary school science textbook (version B) published by the

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Japanese publishing house B were chosen to be the materials of the study. Both versions of the textbooks are now widely used in both countries, and two publishing houses both have claimed to comply with new science curriculum standards for primary schools. The two publishers also provided reference guides for teachers when published the textbooks, the teaching objectives and teaching hours of each lesson were defined in them, such as "Students can list the examples of the compressed air used in production and life". The teaching objectives formed the corresponding relationship with the learning objectives in the curriculum standards, so the teaching objectives in the textbooks became the reference for coding.

Instrument

The Porter's alignment model was chosen to be the instrument to detect the alignment level between a textbook and its corresponding curriculum standard. In this model, a two-dimensional table about the "topic" and the "cognitive demand" was established (Porter, 2002; Porter et al. 2007), so not only the alignment index between the tested textbook and the curriculum standard was clear, but also the alignment of the textbook on topic and cognitive demand were presented respectively. Through the adjustment to the localization of the model, the "topic" dimension was divided into physical science, life science, and earth and space science. The main reason is that the two countries have certain commonalities in the topic division after referring to the specific content of primary school science curriculum standards and textbooks in China and Japan. In the cognitive demand dimension, it was divided into six levels: remember, understand, apply, analyse, evaluate, and create. This classification method was referred to the classification of cognitive process dimension in Anderson's taxonomy (Anderson & Krathwohl, 2001), which was built on Bloom's taxonomy. Anderson further subdivided the six levels into 19 specific items. The specific division is shown in Table 1. This classification method was chosen because some researchers had adjusted the Porter's alignment model and analysed Chinese science standardized tests on this basis (Liu et al. 2009), so it can be considered to be scientific and applicable. By dividing the dimensions of "topic" and "cognitive demand", a 3×6 table was formed.

Table 1
Classification of Cognitive Process Dimension in Anderson's Taxonomy

Cognitive demand	Explanation	Specific items
Remember	Extract relevant information from long-term memory.	Recognize, Recall
Understand	Construct meaning from oral, written, and graphic information.	Interpret, Exemplify, Classify, Summarize, Infer, Compare, Explain
Apply	Execute or applying a program in a particular situation.	Execute, Implement
Analyse	Decompose the material into components and determine the relationship between each part and the overall relationship.	Differentiate, Organize, Attribute
Evaluate	Make judgments based on criteria.	Check, Critique
Create	Integrate elements into a whole with unified functions or reorganize elements into a new structure.	Generate, Plan, Produce

Procedures

After the framework was determined, the text content of curriculum standards and textbooks was analysed and coded. The two coders employed in this study are both researchers engaged in scientific education research and proficient in Chinese and Japanese. They first discussed the framework and clarified the details of the coding. Secondly, two coders coded the curriculum standards and textbooks independently. Thirdly, the two coders' respective coding results were calculated by Kendall correlation coefficient to ensure the scientific results. Finally, they discussed each item together, especially the differences, until a consensus was reached.

Based on the coding results, this study analysed the alignment level between primary school science textbooks and curriculum standards in China and Japan. In order to find out the misalignment between the textbooks

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and the curriculum standards, the two versions of the textbooks were compared and discussed from the topic, cognitive demand, and emphasis.

Data Analysis

To calculate the alignment level of the coding results, the data was normalized to make the sum of the rows and columns of the two-dimensional table was 1, then the two-dimensional ratio tables of curriculum standards and textbooks were obtained (Porter et al., 2007). The data in the tables was substituted into Porter's alignment formula, and Porter's alignment index P was obtained. In the formula, P represents the Porter's alignment index, *n* represents the number of cells in the two-dimensional table, *i* represents a cell in the two-dimensional table, and X and Y represent two objects for alignment evaluating. In this study, they are the tables of the curriculum standards and the textbooks, respectively. Since the tables were normalized, the range of P is 0 to 1, and the larger the P is, the higher the degree of alignment between the two objects is proved; conversely, the smaller the P is, the lower the degree of alignment is proved (Poter, 2002).

$$P = 1 - \frac{\sum_{i=1}^{n} |X_i - Y_i|}{2}$$

Since any two tables are likely to have a certain degree of alignment, it is necessary to find a statistically significant critical value to compare with the alignment index obtained by the Porter's alignment formula. After coding through the Matlab, two 3×6 two-dimensional tables of the textbook and curriculum standard were randomly accessed, the process was executed 20000 times to get the mean and standard deviation of P, and the statistically significant critical value at the 0.05 level was calculated. When the alignment index reaches the critical value, there is a statistically significant alignment between the textbook and curriculum standard (Liu et al., 2009). Next, the clustered column charts were formed to present the alignment from the dimensions of topic and cognitive demand, and the content maps were formed to present the alignment of emphasis.

Research Results

Comparison of Alignment Index

Table 2 presents the learning objectives of the Chinese curriculum standard and the teaching objectives of the A version textbook in ratios separately. The number in each cell represented the ratio of the curriculum standard or textbook in each cognitive demand under each topic. Because of the normalization, the final sum of the part of the curriculum standard or the textbook was 1.

Table 2
Learning Objectives of the Chinese Curriculum Standard and Teaching Objectives of the A Version Textbook in Ratios

		Remember	Understand	Apply	Analyse	Evaluate	Create	Subtotal
Chinese curriculum standard	Physical science	0.190	0.167	0.071	0	0	0.024	0.452
	Life science	0.048	0.143	0	0	0	0	0.191
	Earth and space science	0.143	0.143	0.071	0	0	0	0.357
	Subtotal	0.381	0.453	0.142	0	0	0.024	1
A version textbook	Physical science	0.071	0.161	0.106	0	0	0.034	0.372
	Life science	0.137	0.158	0.037	0.014	0.007	0.020	0.373
	Earth and space science	0.113	0.093	0.032	0	0	0.018	0.256
	Subtotal	0.321	0.412	0.175	0.014	0.007	0.072	1

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Table 3 presents the learning objectives of the Japanese curriculum standard and the teaching objectives of the B version textbook in ratios separately. Similar to Table 2, data comparison could reflect the similarities and differences in the proportion distribution of various topics and cognitive demands between this version of textbook and its corresponding curriculum standard.

Table 3
Learning Objectives of the Japanese Curriculum Standard and Teaching Objectives of the B Version Textbook in Ratios

		Remember	Understand	Apply	Analyse	Evaluate	Create	Subtotal
Japanese curriculum standard	Physical Science	0.175	0.227	0.175	0	0	0.021	0.598
	Life science	0.083	0.113	0.062	0	0	0	0.258
	Earth and space science	0.041	0.052	0.052	0	0	0	0.145
B version textbook	Subtotal	0.299	0.392	0.289	0	0	0.021	1
	Physical science	0.103	0.189	0.162	0	0	0.081	0.535
	Life science	0.105	0.168	0.088	0	0	0	0.361
	Earth and space science	0.033	0.045	0.027	0	0	0	0.105
	Subtotal	0.241	0.402	0.277	0	0	0.081	1

The alignment index was obtained by substituting the data into the Porter's alignment formula, and significant critical value at the level of 0.05 was obtained through Matlab (Table 4). By comparing the alignment index of the two versions of textbooks with their corresponding critical value, it was found that the alignment index of the A version textbook (0.756) was lower than its critical value (0.779), indicating that there was no significant alignment between the A version textbook and the Chinese curriculum standard. However, the alignment index of the B version textbook (0.837) was higher than its critical value (0.776), indicating that the B version textbook had significant alignment with the Japanese curriculum standard.

Table 4
Alignment between Two Versions of Textbooks and Their Curriculum Standards

	Mean	Standard deviation	Alignment index	Critical value
Alignment between the A version textbook and the Chinese curriculum standard	0.676	0.063	0.756	0.779
Alignment between the B version textbook and the Japanese curriculum standard	0.673	0.063	0.837	0.776

Comparison of Alignment from the Topic

In order to more clearly present the ratios of each topic between the textbooks and the curriculum standards in China and Japan respectively, clustered column charts in Figure 1 were formed. In the figure, the abscissa represented the three topics, and the ordinate was the ratio of the topic to the whole content. It was found that between the ratio of the A version with the Chinese curriculum standard in different topics exists obvious inconsistency. Life science had the lowest share in the curriculum standard but became the topic of the highest share in the textbooks. However, the B version and the Japanese curriculum standard were in the same order in the topic dimension, and the ratio gap of different topics was obvious, both highlighted the physical science as the key topic. In addition, an interesting common point was that the textbooks of two versions both set the topic beyond the curriculum standard in the topic of life science, and the ratio of the excess was relatively large. As a result, the topic of physical science and earth and space science could not meet the requirements of the curriculum standard.

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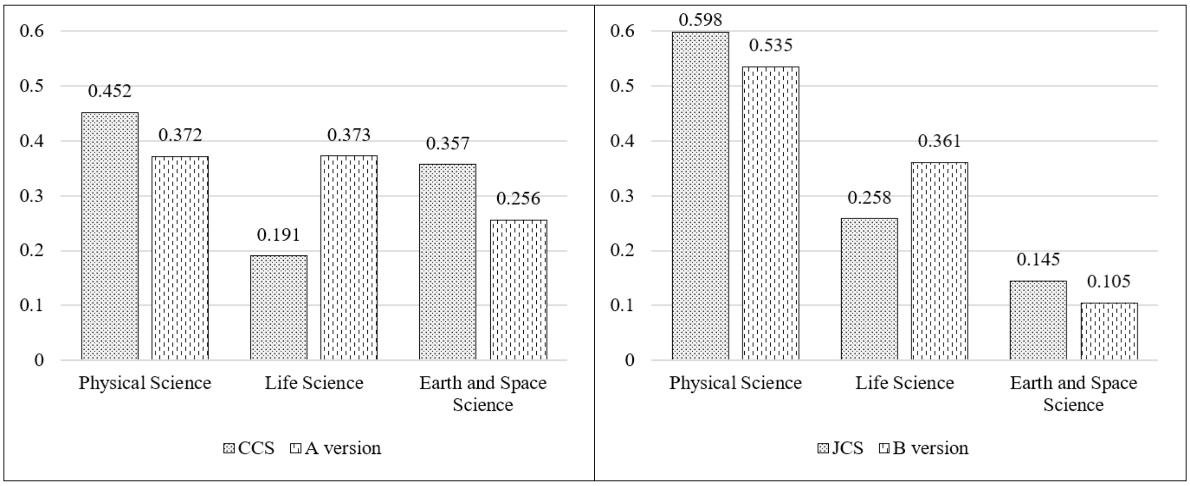
Figure 1

The Ratios of the Chinese Curriculum Standard (CCS) and the A Version Textbook, the Japanese Curriculum Standard (JCS) and the B Version Textbook in the Topic Dimension

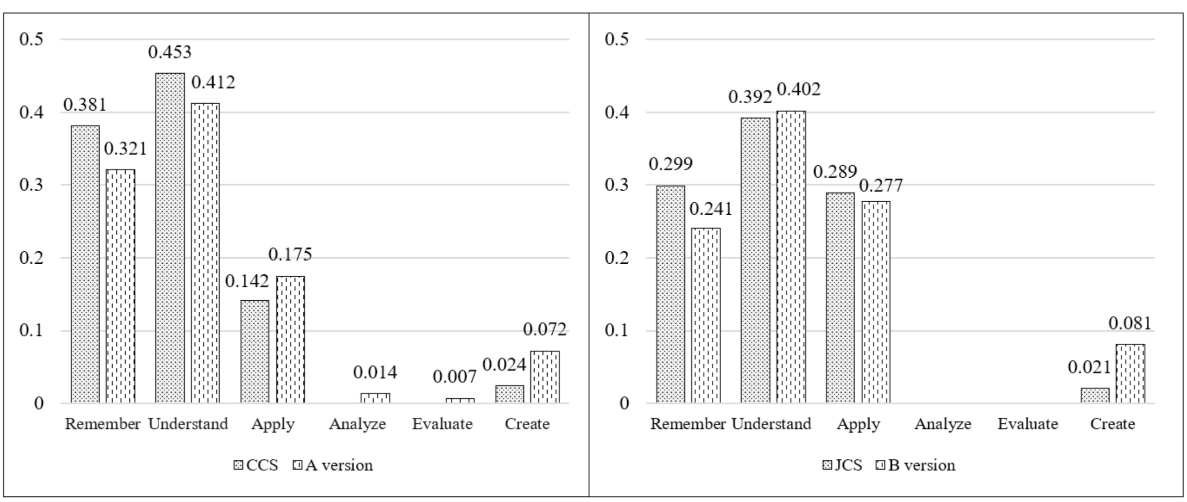


Comparison of Alignment from the Cognitive Demand

Figure 2 shows the alignment between science textbooks and their corresponding curriculum standards at different cognitive demands. In the figure, the abscissa represented the six cognitive demands, and the ordinate was the ratio of the cognitive demand in the whole content. It was found that under certain condition that there were no requirements of analysis and evaluation in the curriculum standards of two countries, the B version did not involve the two cognitive demands, which kept the same with the curriculum standard, but the A version involved the requirements of these two cognitive demands, which appeared different with the curriculum standard. Moreover, it is worth noting that the A version in the two lower cognitive demands named remembering and understanding did not reach the ratio of curriculum standard's requirements, and in the rest of the four higher cognitive demands went beyond the ratio of the curriculum standard's requirements. In other words, the A version put forward higher requirements than curriculum standards for students in cognitive demand, while the B version did not reflect this trend.

Figure 2

The Ratios of the Chinese Curriculum Standard (CCS) and the A Version Textbook, the Japanese Curriculum Standard (JCS) and the B Version Textbook in the Cognitive Demand Dimension



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Comparison of Alignment from the Emphasis

Transformed each two-dimensional table into a content map, the emphasis of curriculum standards and textbooks was further analysed. Figure 3 and Figure 4 show the emphasis of the science curriculum standards and the textbooks of two countries. In figures, the abscissa axis for six cognitive demands, the ordinate axis for three topics, the place transverse and longitudinal axes intersect means the ratio of a certain cognitive demand of this topic in the overall context. Different patterns represented the different ratios, such as the light-coloured dot areas represented the highest ratio, which was between 0.2 to 0.25; the dark vertical stripe areas were the higher part between 0.15 to 0.2; the grid areas meant the moderate part between 0.1 to 0.15; the lower ratio of the dark dotted line areas was from 0.05 to 0.1; the white areas represented the least ratio less than 0.05.

Combined the content maps with the data in the two-dimensional ratio tables, it was found that the B version and the Japanese curriculum standard both focused on the demand of understanding of physical science. However, although the Chinese curriculum standard exceeded the demand of remembering in physical science the most, but the A version shifted the focus to the demand of understanding in physical science, which virtually increased the demand for students' cognitive level. Besides, although in the A version the ratio of understanding level in physical science was higher, but the high level was not obvious, indicating that the A version was not in accordance with the requirements of the Chinese curriculum standard to stress the key point, but spread out the key contents.

Figure 3
The Emphasis of the Chinese Curriculum Standard (CCS) and the A Version Textbook

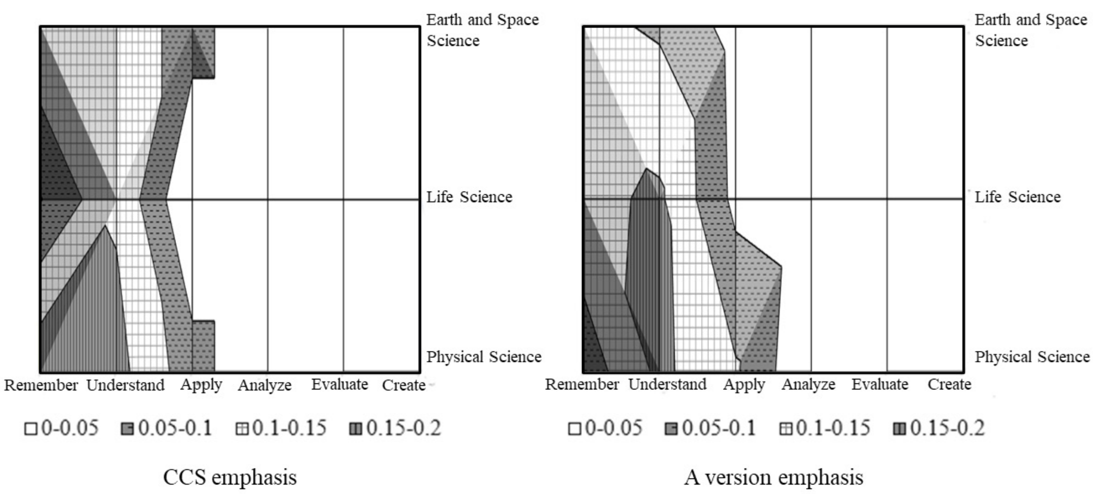
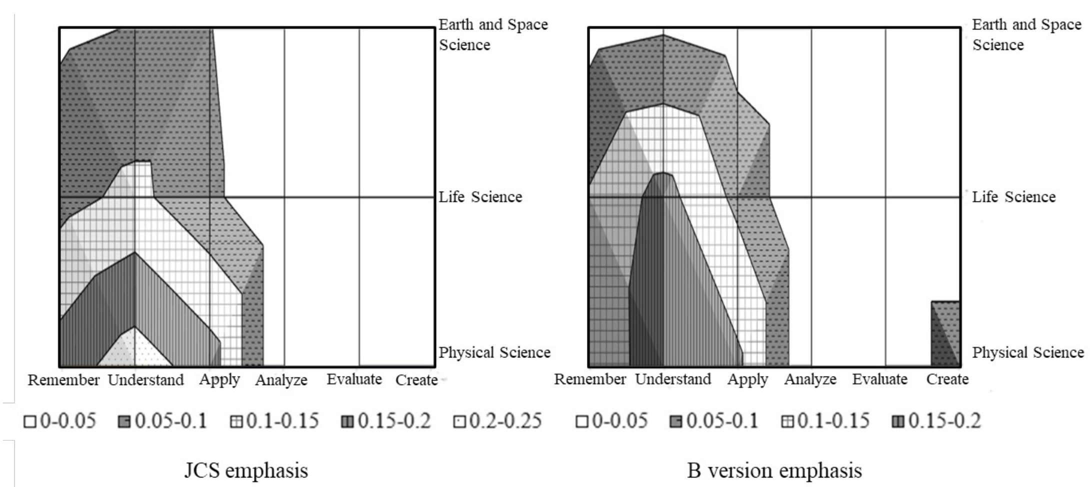


Figure 4
The Emphasis of the Japanese Curriculum Standard (JCS) and the B Version Textbook



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Discussion

Based on the theory of Anderson's taxonomy, this study localized the Porter's alignment model to make it more suitable for the alignment analysis between primary school science textbooks and curriculum standards. After deeply studying the new version of primary school science curriculum standards and representative textbooks in China and Japan, the texts according to the two-dimensional framework were coded. Although researchers have already used the alignment model to conduct an international comparative study of the alignment level between standardized tests and curriculum standards, also whether science textbooks in accordance with the requirement of curriculum standard have been discussed, in the existing study of science textbooks, there is still a lack of research on comparing the alignment level between textbooks and curriculum standards in different countries by using alignment model. This study provides a constructive reference for improving the alignment level between science textbooks and curriculum standards through data analysis and international comparison.

First, there is significant alignment between the B version and the Japanese curriculum standard, but there is no significant alignment between the A version and the Chinese curriculum standard. This indicates that compared with the B version, the A version does not well implement the requirements of curriculum standard in the compilation process and does not form a high level of agreement with the curriculum standard. In view of this result, in the process of the revision and compilation of the A version in the future, it is necessary to deeply study the curriculum standards, carefully analyse where the current textbooks are inconsistent with the curriculum standards, and ensure that the textbooks and the curriculum standards achieve a higher degree of alignment.

Second, the main reason why the A version does not have a high degree of alignment in the topic dimension is that the content of life science is too much, while the content of earth and space science is reduced. This phenomenon also exists in the B version, showing that this is a common problem. Perhaps because textbook writers think that the topic of life science is easier to arrange outdoor observation inquiry activities, while designing the links that can closely contact with the natural environment, can make students engage their senses better, arouse curiosity and interest in learning science, and cultivate the ability of appreciation and aesthetic (Hecht et al., 2019; Jung et al., 2019; Merritt & Bowers, 2020). However, this does not mean that the content of earth and space science can be reduced. Because the study of earth and space science is closely related to the development of students' spatial perception (Aliman et al., 2019; Park et al., 2009), and the middle grade in primary school is an important stage for students to develop spatial perception (Wang et al., 2007). Therefore, when arranging topics of textbooks, textbook writers should be in strict accordance with the curriculum standards for the division of different topics, to ensure that there will not be the ratio of one topic far beyond the curriculum standards, especially for the topic setting of life science and earth and space science, should be paid special attention to.

Third, "Beyond-standards" is a prominent problem in the science textbooks of the A version. Compared with the B version, which carefully follows the requirements of the curriculum standard in the dimension of cognitive demand, it is shown that the A version has exceeded the requirements of the curriculum standard in the setting of the cognitive demand, no matter the content of the lower level of cognitive demands is reduced, the content of the higher level of cognitive demands is added, or the emphasis is shifted. There are two possible explanations for this phenomenon. From a historical perspective, China learned from the Soviet Union's experience in developing science education in the early years of founding, which present the characteristics of high difficulty of knowledge and heavy learning tasks (Cai, 2009). Although with the development of science education, attaching great importance to the independent exploration, highlighting the interesting and inspiring, emphasizing the students' subjectivity and other new features stand out gradually, but the historical factors more or less affect the current textbook writing. From a realistic point of view, the exam-oriented culture has a deep impact on the current education environment in China (Deng et al., 2020). In order to "win at the starting line", students are often expected to learn more and more difficult knowledge, which may prompt the textbook writers to intentionally increase the requirements on students' cognitive demands. However, as Piaget pointed out in his theory of cognitive development, children's cognitive development is a continuous and cumulative process, in which each step of development builds on the previous steps (Wadsworth, 1984). It reminds textbook writers that textbooks should not go beyond children's cognitive development level and blindly pursue advanced development. In fact, China's relevant policies have also strengthened the control of the phenomenon of "Beyond-standards". The Ministry of Education issued the "Negative List of Beyond-standard Training in Compulsory Education" in 2020 (The State Council of the People's Republic of China, 2020), requiring serious investigation and punishment of training behaviours exceeding the standard, and effectively reducing the overweight extracurricular burden of primary and secondary school students. It can be seen that following the law of students' cognitive development and setting the content with reasonable adjustment step by step have become an urgent need to improve the current science textbooks for primary schools in China.

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Finally, the alignment between textbooks and curriculum standards emphasized does not mean that there is no opportunity for the textbooks to show the features. It is not in conflict between following the requirements of curriculum standards and pursuing the innovation and characteristics of textbooks. The B version not only follows the curriculum standard, but also integrates the wisdom and ideas of the textbook writers. For example, as the content of "growth of plants", it was found that in the B version, the content is arranged according to time order. More specifically, the activity of sowing seeds is arranged in April, since the plants need a period to grow, students learn the knowledge of roots, stems, and leaves of plants in June, learn the knowledge of blossom in July, and observe the growth of fruits and the state of withering plants in September. This design is taken into full consideration of the reality and teaching pace. In contrast, the A version is more likely to set these links in a unit, which makes students need to complete the study of this unit within a few weeks. It seems to have a logical system, but in fact it does not follow the law of natural growth, which also brings some troubles to teachers in teaching. Therefore, ensuring a high alignment between science textbooks and curriculum standards is only the basic requirement in the process of compilation. It is an important task that primary school science textbooks should be paid more attention to constantly enrich and improve the details and integrate advanced ideas and unique wisdom into every corner of textbooks in the future.

Conclusions and Implications

In this study, the Porter's model was used to analyse the alignment of the third-grade primary school science textbooks with their corresponding curriculum standards, and the results were discussed from the perspectives of topic, cognitive demand, and emphasis. It was found that the alignment between the A version and the Chinese curriculum standard was lower, which needed to be further improved. The B version performed better at the alignment level, but there were also some places for further improvement. Besides, keeping proper control of the proportion of life science, fully following students' cognitive development levels and avoiding the problem of "Beyond-standards", highlighting the key content of curriculum standard stressed, being aligned with the curriculum standard based on the integrated into the characteristic and wisdom, are all needs to be paid attention to in the process of writing science textbooks.

This study has developed and supplemented the existing research on science textbooks by calculating and comparing the alignment between the two versions of primary school science textbooks and their corresponding curriculum standards in China and Japan. It has been found that there are similarities and differences in the alignment between the two versions of textbooks and curriculum standards. It can be seen that it is meaningful to explore the alignment between science textbooks and curriculum standards in different countries. On the one hand, it will help own country to find out in what aspects the science textbooks can further improve the level of alignment with curriculum standards, on the other hand, countries can also refer to each other's textbooks for points that align with curriculum standards. In addition, other countries with similar educational backgrounds can also get some inspiration.

The current research focuses on whether science textbooks and curriculum standards are aligned, and what are the misaligned points that need to be improved. In the future research, some interviews can be added. As a matter of fact, the compilers of curriculum standards and textbooks are not the same group. The problems that what kind of differences exist in their ideas of science education, how these differences will affect the alignment of science textbooks and curriculum standards, and what kind of impact they will have on science education, need to be further understood and discussed through in-depth interviews with the compilers of curriculum standards and science textbooks.

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Declaration of Interest

Authors declare no competing interest.

References

Abd-El-Khalick, F., Waters, M., & An-Phong, L. (2008). Representations of nature of science in high school chemistry textbooks over the past four decades. *Journal of Research in Science Teaching, 45*(7), 835–855. https://doi/abs/10.1002/tea.20226

https://doi.org/10.33225/jbse/21.20.507

Aldahmash, A. H., Mansour, N. S., Alshamrani, S. M., & Almohi. S. (2016). An analysis of activities in Saudi Arabian middle school science textbooks and workbooks for the inclusion of essential features of inquiry. *Research in Science Education, 46*, 879–900. https://doi.org/10.1007/s11165-015-9485-7

Aliman, M., Budijanto., Sumarmi., Astina, I. K., Putri, R. E., & Arif, M. (2019). The effect of earthcomm learning model and spatial thinking ability on geography learning outcomes. *Journal of Baltic Science Education, 18*(3), 323–334. https://doi.org/10.33225/jbse/19.18.323

Andersen, K. N. (2020). Assessing task-orientation potential in primary science textbooks: Toward a new approach. *Journal of Research in Science Teaching. 57*(4),481–509. https://doi.org/10.1002/tea.21599

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of bloom's taxonomy of educational objectives*. Longman.

Cai, H. (2009). *Science teaching theory in primary school*. Hunan Science & Technology Press.

Çakici, Y. (2012). Exploring Turkish upper primary level science textbooks' coverage of scientific literacy themes. *Eurasian Journal of Educational Research, 49*, 81–102.

Contino, J. (2013). A case study of the alignment between curriculum and assessment in the New York State earth science standards-based system. *Journal of Science Education and Technology, 22*(1), 62–72. https://doi.org/10.1007/s10956-012-9376-x

Deng, L., Wu, S., Chen, Y., & Peng, Z. (2020). Digital game-based learning in a Shanghai primary-school mathematics class: A case study. *Journal of Computer Assisted Learning, 36*(5), 709–717. https://doi.org/10.1111/jcal.12438

FitzPatrick, B., Hawboldt, J., Doyle, D., & Genge, T. (2015). Alignment of learning objectives and assessments in therapeutics courses to foster higher-order thinking. *American Journal of Pharmaceutical Education, 79*(1), Article 10. https://doi.org/10.5688/ajpe79110

Fulmer, G. W., Tanas, J., & Weiss, K. A. (2018). The challenges of alignment for the Next Generation Science Standards. *Journal of Research in Science Teaching, 55*(7), 1076–1100. https://doi.org/10.1002/tea.21481

Gilavand, A., Moosavi, A., Gilavand, M., & Moosavi, Z. (2016). Content analysis of the science textbooks of Iranian junior high school course in terms of the components of health education. *International Journal of Pediatrics, 4*(12), 4057–4069. https://doi.org/10.22038/ijp.2016.7428

Hecht, M., Knutson, K., Crowley, K. (2019). Becoming a naturalist: Interest development across the learning ecology. *Science Education, 103*(3), 691–713. https://doi.org/10.1002/sce.21503

Hill, H. C. (2001). Policy is not enough: Language and the interpretation of state standard. *American Educational Research Journal, 38*(2), 289–318.

Jung, Y. J., Zimmerman, H. T., & Land, S. M. (2019). Emerging and developing situational interest during children's tablet-mediated biology learning activities at a nature center. *Science Education, 103*(4), 900–922. https://doi.org/10.1002/sce.21514

Li, X., Tan, Z., Shen, J., Hu, W., Chen, Y., & Wang, J. (2020). Analysis of five junior high school physics textbooks used in China for representations of nature of science. *Research in Science Education, 50*, 833–844. https://doi.org/10.1007/s11165-018-9713-z

Li, X., Wang, L., Shen, J., Wang, J., Hu, W., Chen, Y., & Tian, R. (2018). Analysis and comparison of scientific inquiry activities in eight-grade physics textbooks in China. *Journal of Baltic Science Education, 17*(2), 229–238. https://doi.org/10.33225/jbse/18.17.229

Liang, L. L., & Yuan, H. (2008). Examining the alignment of Chinese national physics curriculum guidelines and 12th-grade exit examinations: A case study. *International Journal of Science Education, 30*(13), 1823–1835. http://dx.doi.org/10.1080/09500690701689766

Lin, C. (2011). *Learning and development: The development and cultivation of mental ability of primary and middle school students*. Beijing Normal University Publishing Group.

Liu, X., Zhang, B., Liang, L. L., Fulmer, G., Kim, B., & Yuan, H. (2009). Alignment between the physics content standard and the standardized test: A comparison among the United States-New York State, Singapore, and China-Jiangsu. *Science Education, 93*(5), 777–797. https://doi/abs/10.1002/sce.20330

Lu, Q. & Liu, E. (2012). Alignment between high school biology curriculum standard and the standardised tests of four provinces in China. *Journal of Biological Education, 46*(3), 149–164. https://doi.org/10.1080/00219266.2011.645855

Merritt, E. G., & Bowers, N. (2020). Missed opportunities for observation-based ecology in the Next Generation Science Standards. *Science Education, 104*(4), 619–640. https://doi.org/10.1002/sce.21572

Ministry of Education, Culture, Sports, Science and Technology-Japan. (2015). *A school guide for foreign children*. https://www.mext.go.jp/a_menu/shotou/clarinet/003/1320860.htm

Ministry of Education, Culture, Sports, Science and Technology-Japan. (2019). *A survey of international education trends in mathematics and science*. https://www.mext.go.jp/a_menu/shotou/gakuryoku-chousa/sonota/detail/1344312.htm

Ministry of Education, Culture, Sports, Science and Technology-Japan. (2020). *PISA (OECD A survey of students' learning attainment)*. https://www.mext.go.jp/b_menu/toukei/data/pisa/index.htm

Ministry of Education, Culture, Sports, Science and Technology-Japan. (2017). *Primary school study guide essentials*. https://www.mext.go.jp/a_menu/shotou/new-cs/1383986.htm

Ministry of Education, Culture, Sports, Science and Technology-Japan. (2019). *Summary of the deliberations of the education curriculum council*. https://www.mext.go.jp/content/1292164_1.pdf

Ministry of Education of the People's Republic of China. (2019). *Compulsory education law of the People's Republic of China*. Retrieved from http://www.npc.gov.cn/npc/c30834/201901/21b0be5b97e54c5088bff17903853a0d.shtml

Ministry of Education of the People's Republic of China. (2001). *Notice on the issuance of the Outline of Curriculum Reform for Basic Education*. http://www.moe.gov.cn/srcsite/A26/jcj_kcjcgh/200106/t20010608_167343.html

Ministry of Education of the People's Republic of China. (2017). *Science curriculum standards for primary schools in compulsory education*. Beijing Normal University Publishing Group.

ISSN 1648–3898 /Print/
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Newton, J. A., & Kasten, S. E. (2013). Two models for evaluating alignment of state standards and assessments: Competing or complementary perspectives? *Journal for Research in Mathematics Education, 44*(3), 550–580. http://www.jstor.org/stable/10.5951/jresematheduc.44.3.0550

Park, M., Park, D. Y., & Lee, R. E. (2009). A comparative analysis of earth science curriculum using inquiry methodology between Korean and the U.S. textbooks. *Eurasia Journal of Mathematics, Science & Technology Education, 5*(4), 395–411.

Polikoff, M. S. (2015). How well aligned are textbooks to the common core standards in mathematics? *American Educational Research Journal, 52*(6), 1185–1211. https://doi.org/10.3102/0002831215584435

Polikoff, M. S., Zhou, N., & Campbell, S. E. (2015). Methodological choices in the content analysis of textbooks for measuring alignment with standards. *Educational Measurement, 34*(3), 10–17. https://doi.org/10.1111/emip.12065

Porter, A. C. (2002). Measuring the content of instruction: Uses in research and practice. *Educational Researcher,31*(7), 3–14. https://doi.org/10.3102/0013189X031007003

Porter, A. C., Blank, R., & Zeidner, T. (2007). Alignment as a teacher variable. *Applied Measurement in Education,20*(1), 27–51. https://doi.org/10.1080/08957340709336729

Qhibi, A.D., Dhlamini, Z.B., & Chuene, K. (2020). Investigating the strength of alignment between senior phase mathematics content standards and workbook activities on number patterns. *Pythagoras, 41*(1), 1012–2346. https://doi.org/10.4102/pythagoras.v41i1.569

Røthing, A. (2017). Sexual orientation in Norwegian science textbooks: Heteronormativity and selective inclusion in textbooks and teaching. *Teaching and Teacher Education, 2017* (67), 143–151. https://doi.org/10.1016/j.tate.2017.06.005

Rothman, R., Slattery, J. B., Vranek, J. L. & Resnick, L. B. (2002). *Benchmarking and alignment of standards and testing*. Center for the Study of Evaluation, National Center for Research on Evaluation, Standards, and Student Testing, Graduate School of Education & Information Studies, University of California.

The State Council of the People's Republic of China. (2020). *Circular of the general office of the ministry of education on the issuing of the Negative List of Beyond-standard Training in Compulsory Education*. http://www.gov.cn/zhengce/zhengceku/2020-05/11/content_5510519.htm

Troia, G. A., Olinghouse, N. G., Zhang, M., Wilson, J., Stewart, K. A., Mo, Y., & Hawkins, L. (2018). Content and alignment of state writing standards and assessments as predictors of student writing achievement: an analysis of 2007 National Assessment of Educational Progress data. *Reading and Writing, 31*(4), 835–864. https://doi.org/10.1007/s11145-017-9816-3

Tian, H. (2015). *Basic education in Japan*. Tongji University Press.

Vojíř, K., & Rusek, M. (2021). Preferred chemistry curriculum perspective: Teachers' perception of lower-secondary school textbooks. *Journal of Baltic Science Education, 20*(2), 316-331. https://doi.org/10.33225/jbse/21.20.316

Wadsworth, B. J. (1984). *Piaget's theory of cognitive and affective development.* Longmen.

Wang, G., Ye, Z., & Lin, C. (2007). *Psychology of primary school children*. Zhejiang Education Publishing House.

Webb, N. L. (1999). *Alignment of science and mathematics standards and assessments in four states*. National Institute for Science Education, University of Wisconsin-Madison, Council of Chief State School Officers.

Yacoubian, H. A., Al-Khatib, L., & Mardirossian, T. (2017). Analysis of the image of scientists portrayed in the Lebanese national science textbooks. *Science & Education, 26*, 513–528. https://doi.org/10.1007/s11191-017-9908-0

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